GRAPHENE-CA

Coordination Action for Graphene-Driven Revolutions in ICT and Beyond

Coordination and support action

WP2 Economic feasibility, financial plan and sustainability

Deliverable 2.2 “Report on the status of graphene research activities and planned investments”

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TABLE OF CONTENTS

Deliverable Summary

During the first phase of the Coordination Action, the Pilot Consortium has undertaken a comprehensive collection of information concerning graphene research activities and funding in Europe in order to map existing efforts and prepare the financial plan for the full Flagship proposal. This report provides the current status and planned activities as of October 2011.

In order to obtain information across Europe, data was collected through different sources, namely:

- Graphene Flagship web portal open for registration to research groups
- Funding agencies addressed through a dedicated survey
- Web search of online project databases
- European Commission portal CORDIS

The general approach used was to include in the statistics funding corresponding to individual grants, research projects, programmes, networks and centres of excellence. Permanent salaries, funding of research infrastructures and other in-kind contributions from organisations were not included since this information is not readily available and is difficult to estimate accurately. The main focus is therefore on the level of national public funding for graphene-related research projects in EU member states and several associated countries. Europe is already investing significant resources in graphene research and technology, a large part of which via national bodies. The estimated total amount is about 150 M€ spread over several years. Additional 68 M€ have been announced recently and will contribute to the overall funding in the forthcoming years. Taking into account the duration and budgets of the projects, the corresponding national funding for 2011 is of the order of 45 M€/year.

The number of graphene-related projects funded by the European Commission is rapidly increasing and activities are supported through the “People”, “Ideas” and “Cooperation” programmes. A significant part is invested in people and training through Marie Curie Actions and ERC grants which represent a strong basis for future excellence in the field. It will be fundamental, in next years, to ensure that this investment in human resources has a beneficial impact on European competitiveness, avoiding “brain drain” of highly skilled researchers. Collaborative Research is mainly supported within the NMP and ICT programmes with an estimated total amount of 37 M€, corresponding to 9 M€/year in 2011.

The analysis of scientific publications shows that Europe is leading with a 36% share of publications worldwide. The situation is however reversed when the number of patents is considered and Europe with its 12% of the total patent share falls behind Asia (45%) and the United States (40%).

The current data and trends observed, namely the level of national funding and the foreseen launching of new national initiatives in several countries, combined with the additional funds from the EC expected to be available through the Flagship programme, indicate that the Graphene Flagship would be sustainable during the ramp-up phase to begin in 2013. The preparation of the second phase under Horizon 2020 will require additional long-term planning and insight into the instruments and budgets both at the national and EC level.

Introduction

The aim of this report is to provide insights into current and planned investments in graphene-related research in Europe as a first step towards the preparation of the financial plan for the full Flagship proposal. The main focus is on national and EU funding of graphene-related research projects, programmes and networks as data on these activities could be gathered from the different sources addressed in this report. Funding from the European Commission is analysed and compared to the national funding. Due to the intrinsic difficulty in obtaining accurate and reliable information on funding of personnel, research infrastructures and private investments common to most fields of research, these aspects have been addressed only qualitatively.

A very important contribution to this report was given by the national representatives across Europe who actively provided data and feedback on initiatives and funding in their respective countries and which have been included in the Annexes. The Pilot Consortium would like to thank them for their cooperation.

1 Description of data collection and methodology

1.1 Sources and timeline

The overall plan for gathering information on graphene-related funding in Europe was finalized in June 2011 and submitted to the EC in the deliverable 2.1. In order to obtain information from all Europe, data was collected though different sources, namely:

- The **web portal**[1] where individual groups have been registering and providing information on research activities and funding. The web portal has been actively promoted within the scientific community and groups across Europe have been encouraged to register. The number of registered groups is currently 467[2] and constantly increasing. Despite the fact that the scientific community itself is certainly the most up-to date source of information, this approach potentially results in multiple registrations by researchers within the same group, doubling of multi-partner projects and insertion of data that is not directly relevant to the present study. It provides however, the only reliable way of collecting up-to date information on personnel and research topics.
- **Funding agencies** were addressed through a dedicated survey issued by the ESF in June 2011 with a closing date at the end of August 2011. In total more than 40 organisations were contacted by the ESF and 11 of them replied and provided data either directly or through the national representatives. Several countries which are currently funding a large number of projects provided information in the form of documents with relevant data extracted from their

[1] http://www.graphene-flagship.eu/

[2] On 13th October 2011

databases. In some countries where information is not centrally available, the national representatives collected and provided the information. An overview of the responses collected per country is available in Annex B.

- Several organisations have public searchable online project databases and for these the ESF office has performed a **web search** to identify the relevant projects. The information was then cross-checked by national representatives and/or contacts in funding organisations.

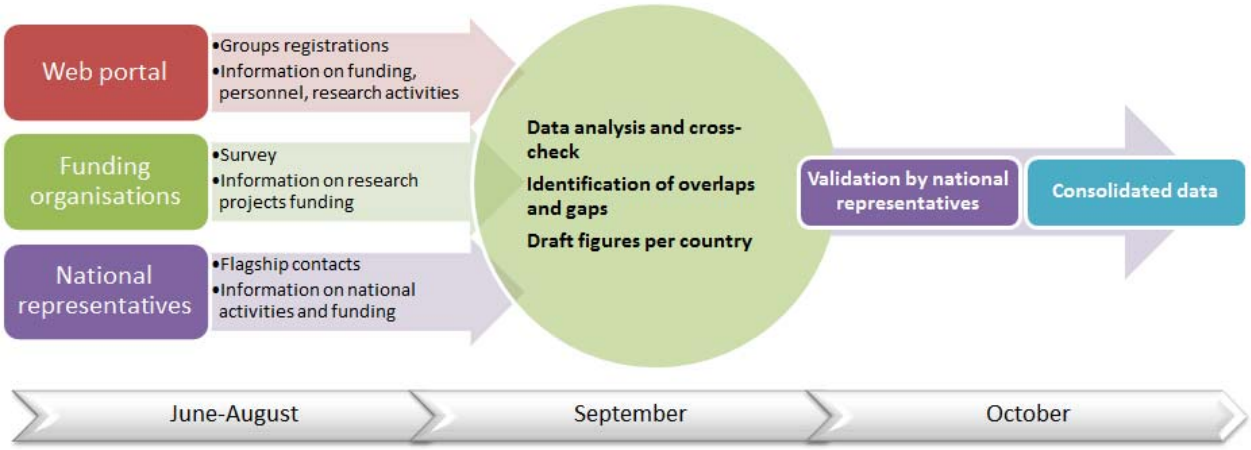


Figure 1.1 Data collection process and timeline

1.2 Data analysis and verification

The data on graphene research activities was collected using various sources, therefore it was necessary to carefully cross-check the information to avoid duplication and identify gaps. In particular, data received via the web portal through the spontaneous registration of the research groups contained a high degree of inaccuracy due to incomplete filling of the forms, errors in funding and personnel figures and inclusion of activities not directly relevant to graphene-research. The information that was obviously incorrect (partner vs. total funding inverted, amounts in € instead of k€, etc.) was identified by the Phantoms Foundation, responsible of the portal, and the ESF and the respective contact persons were requested to provide correct data.

All data received from the web portal, the national funding agencies and national representatives were consolidated and processed as follows:

- All projects were cross-checked for doubles and removed in case the Principal Investigator was entered more than once for the same project
- Amounts indicated in currencies other than Euro were converted with a currency converter[3].
- Incomplete and potentially inaccurate data were identified and marked so that the national representatives could amend them.

[3] www.oanda.com

Resulting data per country was sent to the respective national representatives for validation with a request to : update the data with relevant new information for their country ; signal projects in the list that were not graphene-related and add other projects related to graphene which were not yet in the list. Furthermore, national representatives summarised the main scientific activities, funding and infrastructures in a “Summary report per country” available in Annex B.

2 Analysis of graphene research activities and funding

In this chapter, we present the analysis of current investments in graphene research and technology based on the information collected via the different sources described previously. Depending on the country and the respective national funding system, the access to such information is more or less straightforward. Consequently, the quality and completeness of data can vary significantly across countries. The overview of the responses and sources available per country is presented in Annex B.

Funding provided by the European Commission is described in section 2.2 and includes data on projects within the 7th Framework programme. EU funding sources like structural funds, COST, Article 185 initiatives, etc., are generally not included in the statistics unless mentioned explicitly. The data collected as received from different sources have been cross-checked in order to avoid overlaps and then submitted to national representatives for validation.

The general approach used was to include in the statistics funding corresponding to **individual grants, research projects, programmes, networks and centres of excellence.** The search was done in most cases by using “graphene” as keyword in the abstract or title. In this way, the amounts purely corresponding to graphene research are most likely overestimated. This has to be taken into account when considering the overall amounts and investments. Permanent salaries are not included in these statistics unless they are part of the research projects. Major research infrastructures such as laboratories and dedicated centres are treated separately in section 2.1.5 and in Annex B.

2.1 National funding

In most areas of science, national funding provides the largest part of resources for research activities. In this chapter, we focus on the **national public funding** from EU member states and several associated countries. Therefore, in this first analysis we exclude contributions from industry and in-kind contributions from various institutions which are extremely difficult to estimate accurately.

The overall funding per country is presented in the table below and shows the different contributions based on the data collected through this study. **It is estimated that the total national funding of graphene-related research projects amounts to about 150 M€ spread over several years.** Additional **68 M€** have been announced recently and will contribute to the overall funding in the forthcoming years.

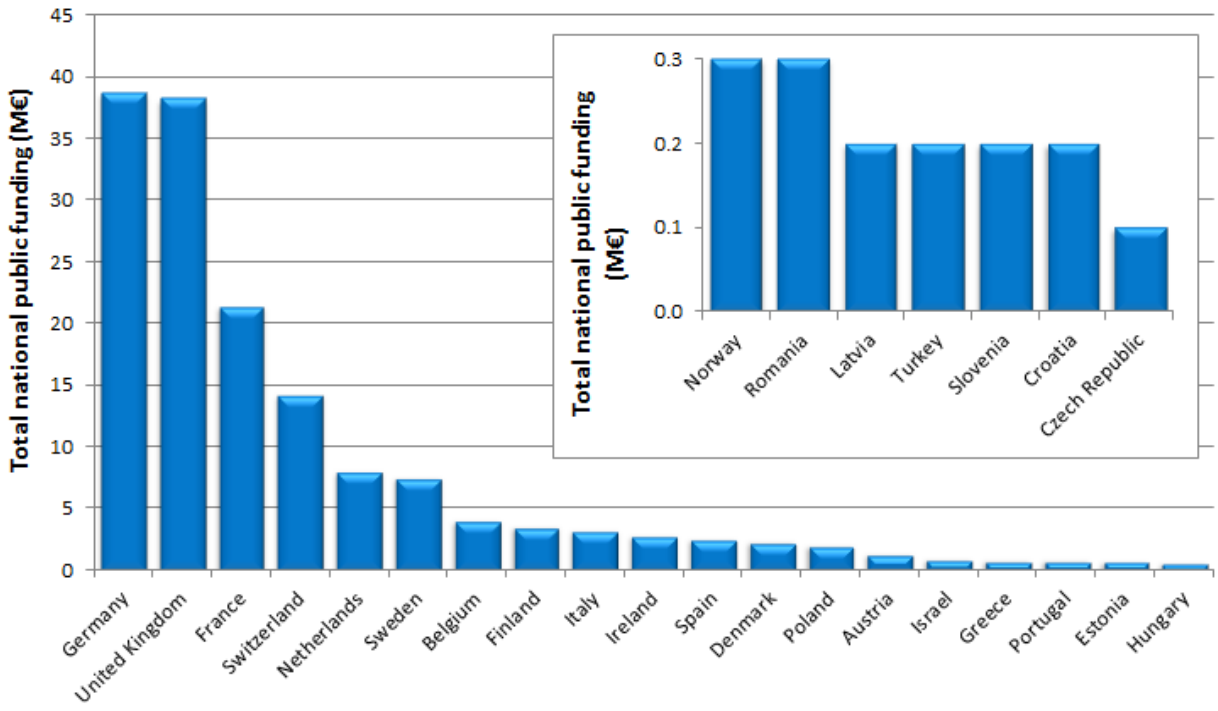


Figure 2.1 National (public) funding for graphene research per country.

Based on the duration and funding of the different projects, the corresponding level of funding per year can be estimated. A strong increase in funding has been observed during the past years and it can be expected that this trend will continue in the future. The decrease in funding after 2011 is explained by the ending of currently running projects while the information on projects starting in 2012 and beyond is not yet available. For 2011, the expected level of funding from EU and Associated countries is of the order of **45 M€/year.**

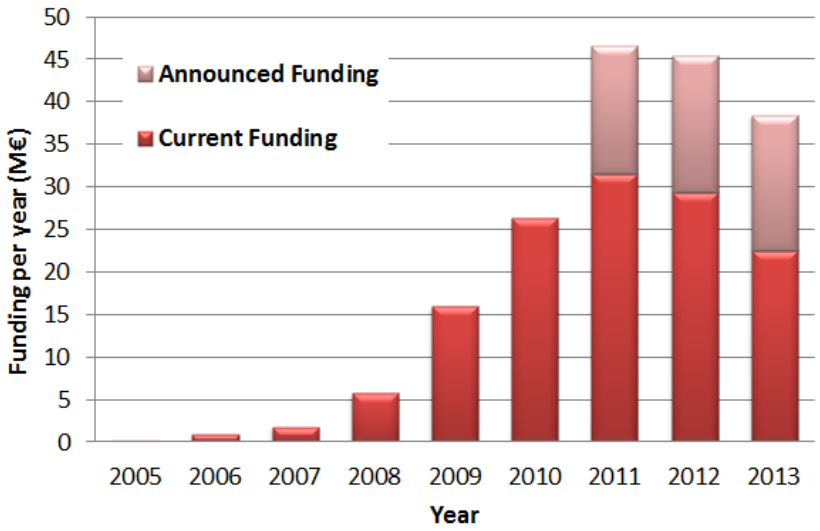


Figure 2.2 Estimated national funding for graphene research per year

2.1.1 Priority programmes

Several countries have initiated priority programmes dedicated to graphene during the past few years, the major in terms of funding being in UK and Germany. Very recently, a number of new initiatives has been announced and are expected to contribute significantly to future funding in the area. These have been included in the table below. Other future initiatives that are still in preparation or under evaluation are described in Chapter 4.

Country	Initiative	Duration	Budget
United Kingdom	*- Graphene Global Research and Technology Hub*	Announced 2011-2014	57 M€ (£50 M)
	- EPSRC Science & Innovation Awards for 'Maximising impact of graphene research on innovation through physics, chemistry and engineering' and 'Graphene Centre'	2009-2014	15 M€
Germany	*- DFG Priority Programme on graphene - SPP 1459*	2010-2016	10.7M€ (for first 3 years)
	- BMBF Programme WING-Graphen	2010-2013	8 M€
Denmark	*Programme on nanostructured graphene by the Danish National Research Foundation (DNRF)*	Announced 2012-18	7.2M€ (54M DKK)
France	*- Graphene-related activities at CEA*		6.6 M€
	- "Graphene and Nanotubes: science and applications" ("GNT") national research group (GDR 3217) and international coordination network (GDRI)	Ongoing	Network
Sweden	*Knut and Alice Wallberg Foundation grant for graphene*	Announced	4.4 M€
Netherlands	*FOM Programme "Graphene-based electronics"*	2007-2011	3.3 M€
Spain	*MICINN Supporting action "Graphene – A mobilizing action in an emerging field"*	Ongoing	Network/national coordination action

Table 2.1 Major national funding initiatives and priority programmes

2.1.2 National networks

Large initiatives supporting ***national networks*** of graphene researchers have been set up in France and Spain. The French community is organized around the "Graphene and Nanotubes: science and

applications" (GNT)[4] group combining a national research group (GDR 3217) and an international coordination network (GDRI) cross-linking research on nanotubes and graphene. The group also includes European and Canadian partners and has, amongst other activities, organized a series of workshops to provide input to the graphene roadmap.

The Spanish network of groups working on Graphene ("GAPHěNE")[5] coordinates the national research community and promotes links between theoretical and experiment groups, academics and industrial partners. It coordinates Spanish contributions to EU initiatives such as the Graphene Flagship and organizes networking and dissemination activities.

The European Science Foundation is currently coordinating the European Collaborative Research Programme (EUROCORES) "Maximising the Impact of Graphene Research in Science and Innovation (EuroGRAPHENE) which supports 32 nationally funded Individual Projects forming 7 Collaborative Research Projects for a total of 7M€. The programme includes a 0.4 M€ budget for networking activities. The funding for the individual projects of EuroGRAPHENE has been included in the corresponding national funding.

2.1.3 National projects

The estimation of the number of projects in different countries was made by taking into account the nature and type of activities. Depending on the particular funding instrument, projects could be divided into individual, collaborative (multi-partner) and multi-lateral (cross-border). The quality of the data collected did not permit an accurate estimate per type of activity therefore only the total number of projects is presented here. It is to be noted that in case of priority programmes involving many single projects, each project with a distinguishable title has been counted individually. Collaborative projects including several partners were counted as one project.

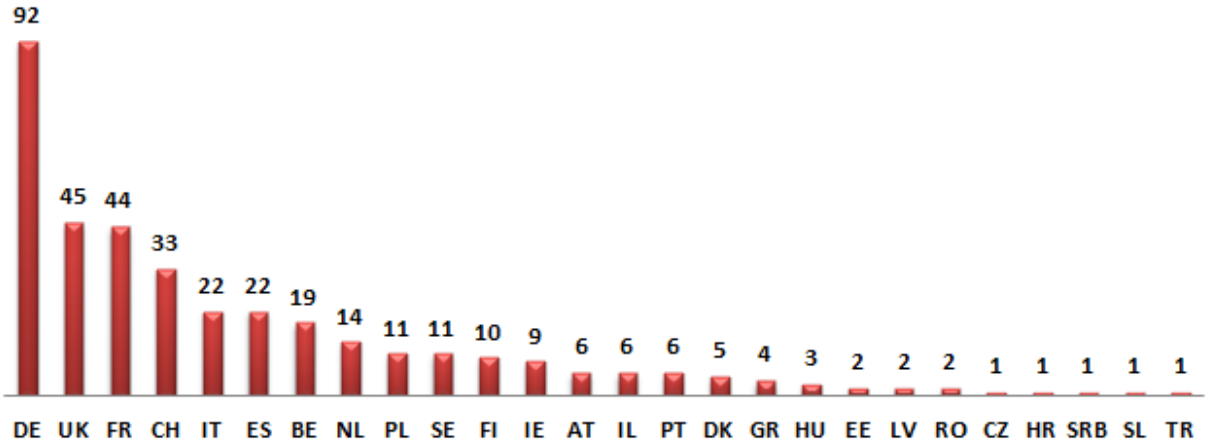


Figure 2.3 Number of national projects per country included in this study.

[4] http://www.graphene-nanotubes.org/

[5] http://www.icmm.csic.es/graphene/

2.1.4 Institutions and funding distribution

The projects considered above are funded by public funds and involve different types of organisations. The main share of funding goes to universities (78%) and research centres (17%). The participation of companies is about 4% which can be explained by the fact that private funding has not been taken into account due to lack of reliable data. The data show that most projects are funded at the level of national funding agencies and governments (91%) while only 9% is supported from local and regional sources. It should be stressed that this proportion of local investment is likely to be underestimated due to the unavailability of data concerning local and regional funding. Some information concerning activities at regional level can be found in the Annex B for countries that have provided such information.

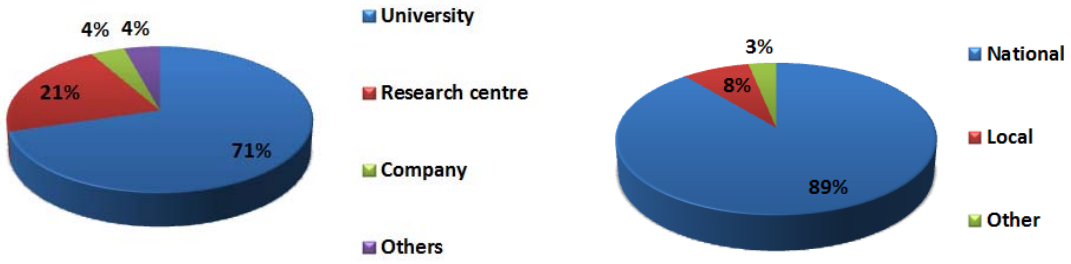


Figure 2.4 Type of institutions involved in graphene research (left) and sources of funding (right)

2.1.5 Research Infrastructures

A significant contribution to research activities is provided through the support of research infrastructures at the national and European level. Such facilities may include synthesis, processing, characterisation and computational tools, synchrotrons, clean rooms and large equipment needed to produce and investigate materials properties, develop graphene-based technologies and devices. In most cases these facilities are located in one single country and may be supported by different sources of funding. Access rules depend on the management of the host organisation and may be open to external users (with or without fee) or restricted to internal use only. Due to the intrinsic difficult in accurately determining the level of funding for these facilities, an in-depth analysis of funding was not carried out in the context of the present study.

The map 2.5 shows an overview of the distribution of infrastructures and equipment used for graphene research as provided by the national representatives. Examples and details on particular infrastructures and equipment are given in the summary report per country in Annex B. It is to be noted that some of the facilities and tools listed are not be currently used for graphene research only and therefore no estimate on the corresponding level of funding could be made in the present report.

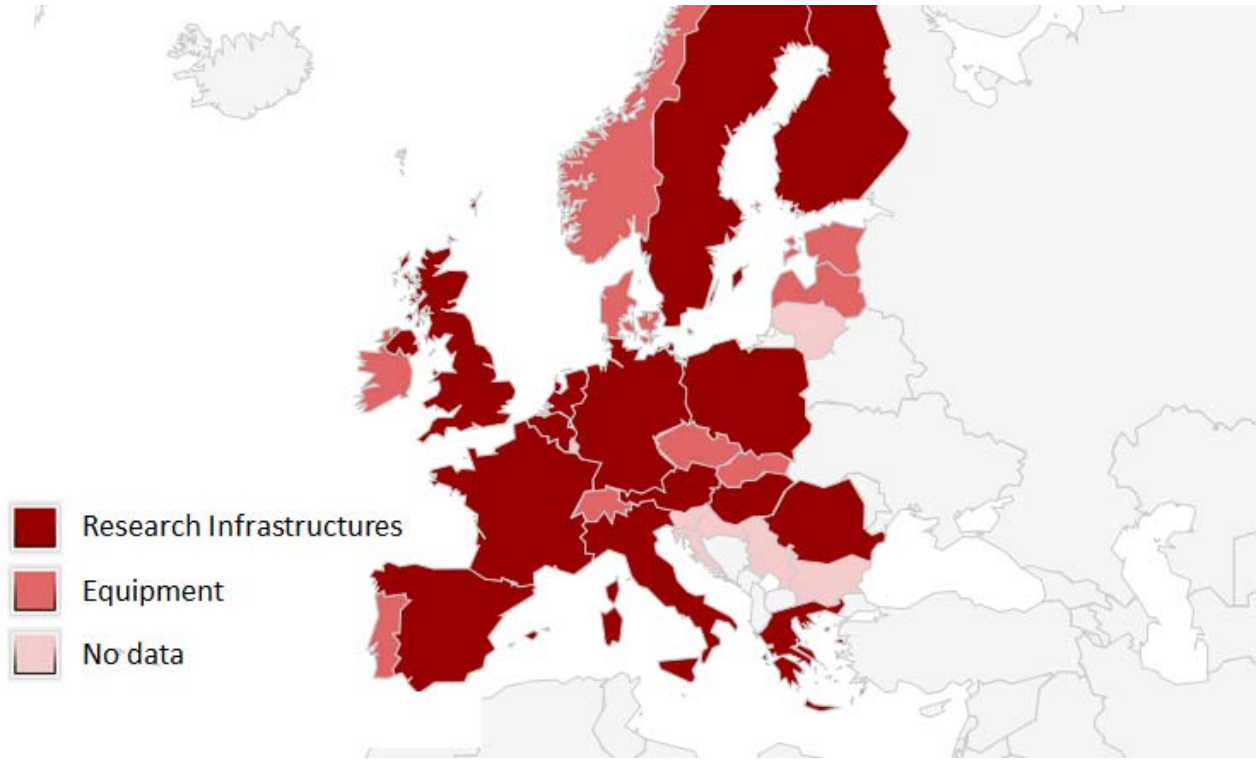


Figure 2.5 Map of countries with research infrastructures and equipment used for graphene research. Source : Annex B.

2.2 European Commission funding

The European Commission has provided funding for graphene research form the early stage, firstly though its bottom up mechanisms such as the European Research Council (ERC) grants and Marie Curie Actions. Professor Konstantin Novoselov was awarded the ERC Starting Grant in 2007 for his project on graphene and he subsequently received the 2010 Nobel Prize in Physics together with Professor Andre Geim, which represents an ERC success story of highest impact.

For the purpose of this report, the projects included in the statistics are the ones that explicitly address graphene in their abstract or workplan. It is clear that such an approach still probably overestimates the corresponding funding level dedicated to graphene research only. It is however expected that it provides a comprehensive snapshot of the current situation where research in related areas (carbon nanotubes, semiconductor nanowires and quantum dots, spintronics and other two-dimensional materials) impacts the studies on graphene since they address related issues from the point of view of materials synthesis and characterisation techniques, theoretical investigations, device properties and integration.

The number of graphene-related projects funded by the EC is rapidly increasing and based on the data available through the CORDIS portal in October 2011, 64 projects (listed in Annex A) were included in the analysis as either directly or partially related to graphene.

Graphene-related science and technology research is supported through the “People”, “Ideas” and “Cooperation” programmes. Marie Curie Actions, account for 50% of the overall number of projects. Further analysis shows that the largest fraction of Marie Curie grants fall into the reintegration or incoming fellowships[6] (ERG) and Intra European Fellowships (IEF). This indicates that the research topic as such is attractive to researchers from Europe or outside to establish themselves and carry out their research in European or Associated countries.

The ERC awarded 19 individual grants to graphene and related topics out of which 12 are Starting Grants. These represent 37% in terms of overall funding.

Collaborative Research Projects (within NMP and ICT combined) amount to a total of 37 M€. A dedicated NMP call on “Nano-structured materials based on graphene” (NMP-2009-2.1-1) was published in 2008 and resulted in the funding of two collaborative research projects.

In terms of networks, besides the FET Flaghship Pilot Coordination Action there is one Initial Training Networks focused on graphene (GENIUS). Two other Initial Training Networks (NANOCTM and SUPERIOR) partly cover graphene-related aspects and the COST Action MP0901 is also supporting networking activities in the field.

[6] Reintegration Grants (RG) and Career Integration Grants (CIG)

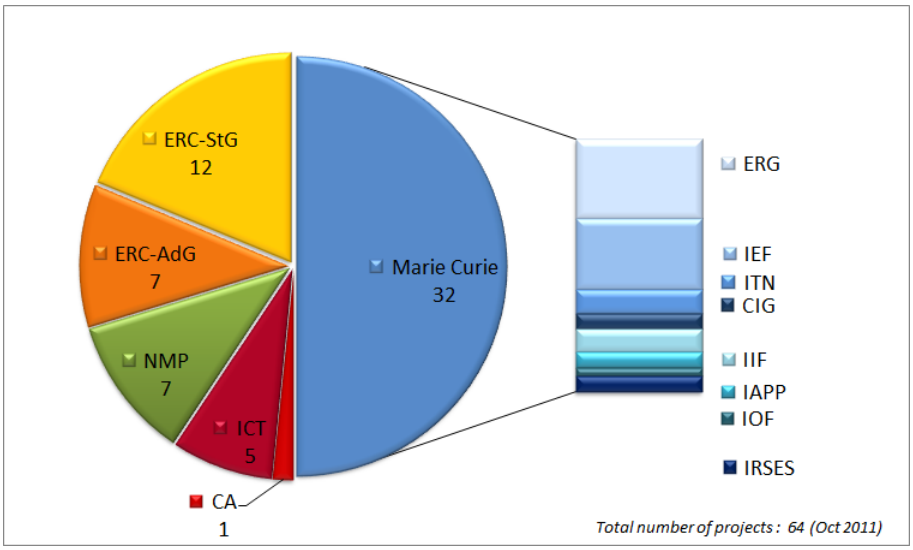


Figure 2.6 Number of EC funded projects per type of instrument. Souce : CORDIS, Oct. 2011.

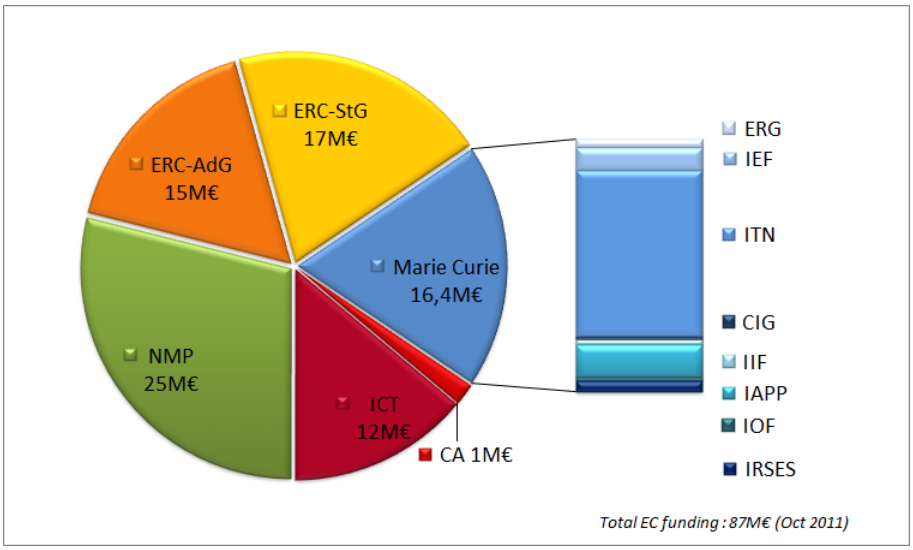


Figure 2.7 EC funding per type of instrument. Souce : CORDIS, Oct. 2011.

The funding per year corresponding to the different instruments is calculated by taking into account the total funding and the duration of the projects showing a strong increase over the past few years across all types of activities. ***In 2011, the largest part of research funding is provided through the NMP (6 M€/year) and ICT (3 M€/year) programmes.*** The starting and advanced ERC grants account for about 5 M€/year although it may be argued that the actual amount granted for graphene-related research is probably smaller. The same is true for Marie Curie actions which have a broader scope and cover other areas of research as well.

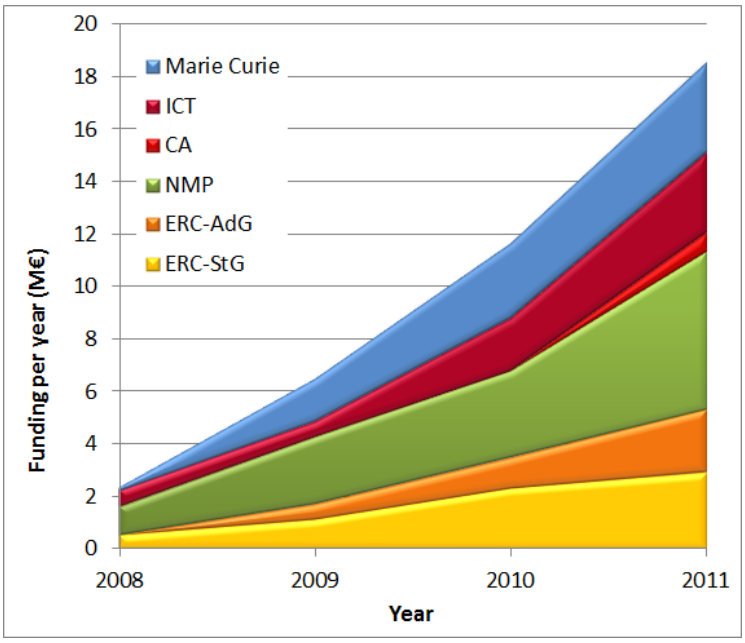


Figure 2.8 EC funding of graphene-related projects in the period 2008-2011

2.3 Combined EC and national funding and Flagship sustainability

A projection into the first phase of the Flagship can be made based on the data presented above and taking into account current levels of funding at national and EU level dedicated to graphene research. When considering the total funding per year, the observed trend is that both at the national and EU level, investments in graphene-related research have been increasing rapidly during the past few years. Before 2008, there was only a very small number of projects devoted to graphene as explained by the recent discovery of the material and the time needed to prepare grants and allocate dedicated funding. Funding cycles in different countries also have to be taken into account since they can vary from one to several years. Based on the reports by national representatives, in several countries, research grants are under preparation and proposals submitted with outcomes expected during 2012 as highlighted in Chapter 4. Significant measurable funding in terms of research grants dedicated to graphene at the national and EC started in 2008 and has so far increased every year. In 2011, the combined total national and EC funding for graphene research is estimated around 65 M€/year.

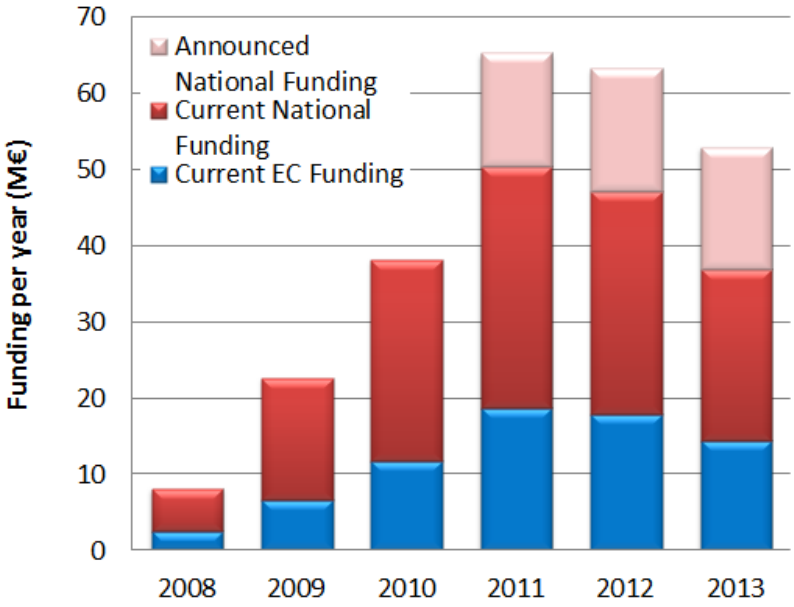


Figure 2.9 Combined National and EC funding per year.

The decreasing trend appearing in the graph after 2011 is due to the fact that information on projects that will start in 2012 and beyond is not yet available and was therefore not included in the statistics. Only the already *committed and approved funding* is depicted in Figure 2.9.

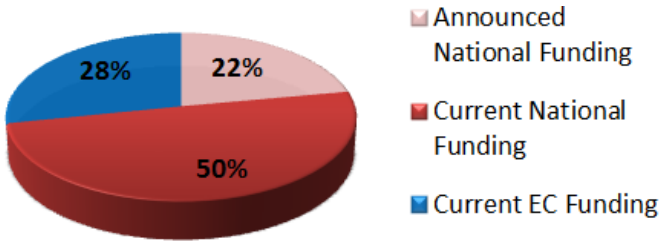


Figure 2.10 Total current investments in graphene at national and EC level

From the EC side, investment in people and training has been very significant which represents a strong basis for the future in particular in new emerging areas. It will be fundamental, in next years, to ensure that this investment in human resources has a beneficial impact on European competitiveness, avoiding “brain drain” of highly skilled researchers.

The figures and the trends observed, namely the current level of national funding and the foreseen launching of new national initiatives in several countries, combined with the additional funds from the EC expected to be available through the Flagship programme, indicate that the Graphene Flagship would be sustainable during the ramp-up phase to begin in 2013. The preparation of the second phase under Horizon 2020 will require additional long-term planning and insight into the instruments and budgets both at the national and EC level.

2.4 Scientific areas

Graphene is often referred to as one of the most versatile materials available to mankind. While it offers promises in several fields of applications, research in many directions is needed to assess its full potential. The roadmap for graphene and related materials which is currently under development will address these issues and outline the directions for future research.

For the present report, the information on activities per scientific area was gathered via the spontaneous registration and information provided by researchers through the Graphene-Flagship web portal [7]. This information is regularly updated and can be consulted online.

The recent statistics show that the highest number of groups is active in the area of nanoelectronics followed by synthesis and growth techniques. It is to be noted that these data have not been checked by the Consortium, but it is considered as the most reliable and up-to date source of information concerning current strengths and interests within the scientific community.

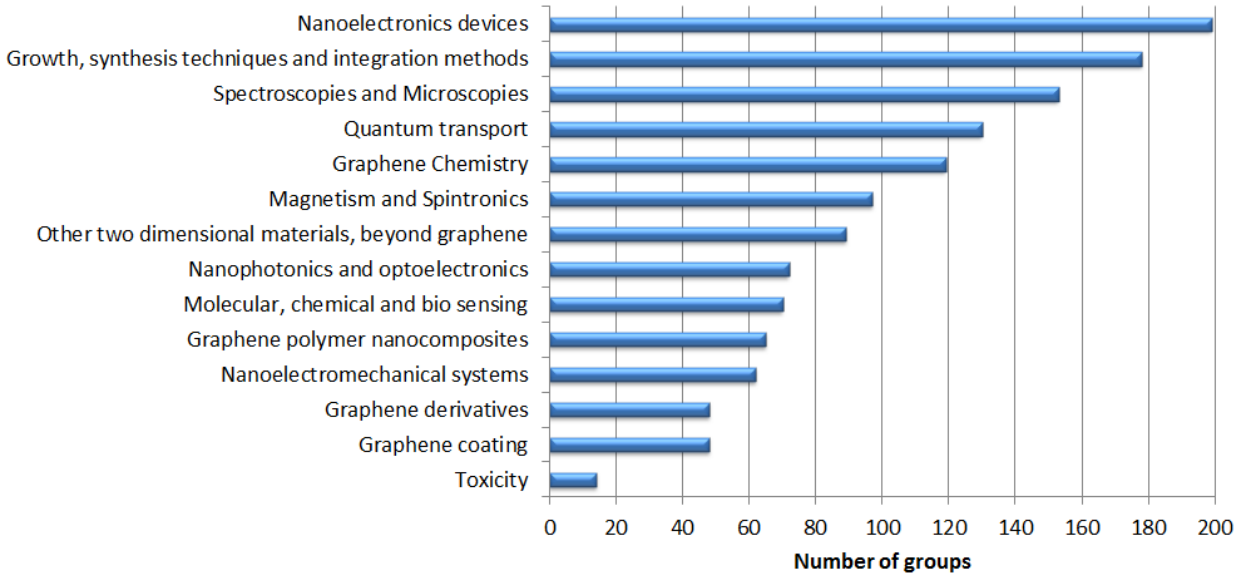


Figure 2.11 Number of groups active in different research areas as registered through the Graphene Flagship web portal (October 2011).

[7] http://www.graphene-flagship.eu/GFreg/statistics.php

2.5 Publications and patents statistics

A detailed analysis of graphene publications was published by Thomson Reuters in the "Global Research Report on Materials Science and Technology"[8] which highlights graphene as one of the three "hot topics" in materials science.

The analysis per world regions shows that Europe is leading in terms of number of publications with a total share of 36% of published papers.

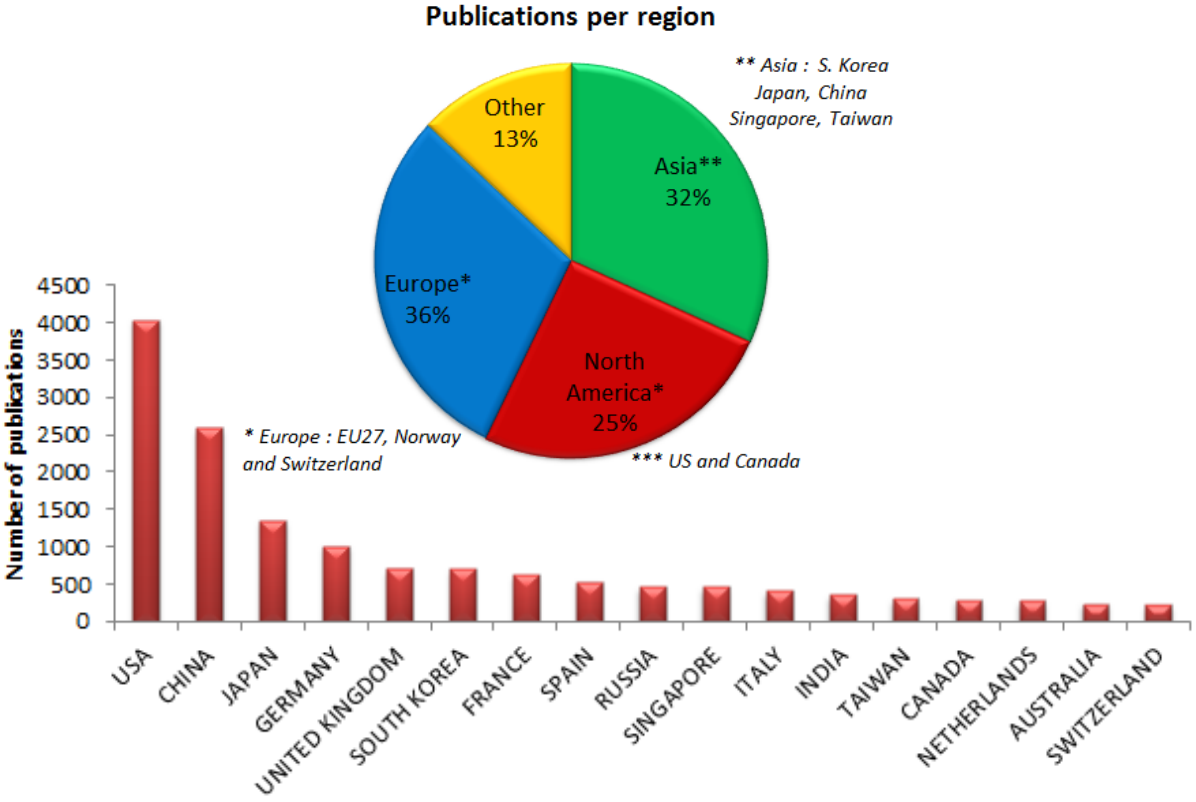


Figure 2.12 Share of publications on graphene per world region (top) and number of publications per country (bottom). Source : Web of Knowledge, September 2011.

An updated extraction of graphene-related patents was made through the European Patent Office portal[9] by using "graphene" as a keyword. The search was performed by applicants' and inventors' host country with at least one affiliation in the given country. The results show that the highest activity is taking place in Asia and the United States. European countries possess a share of 12% of the total number of patents.

[8] http://interest.science.thomsonreuters.com

[9] http://worldwide.espacenet.com, data extracted on 7/09/2011

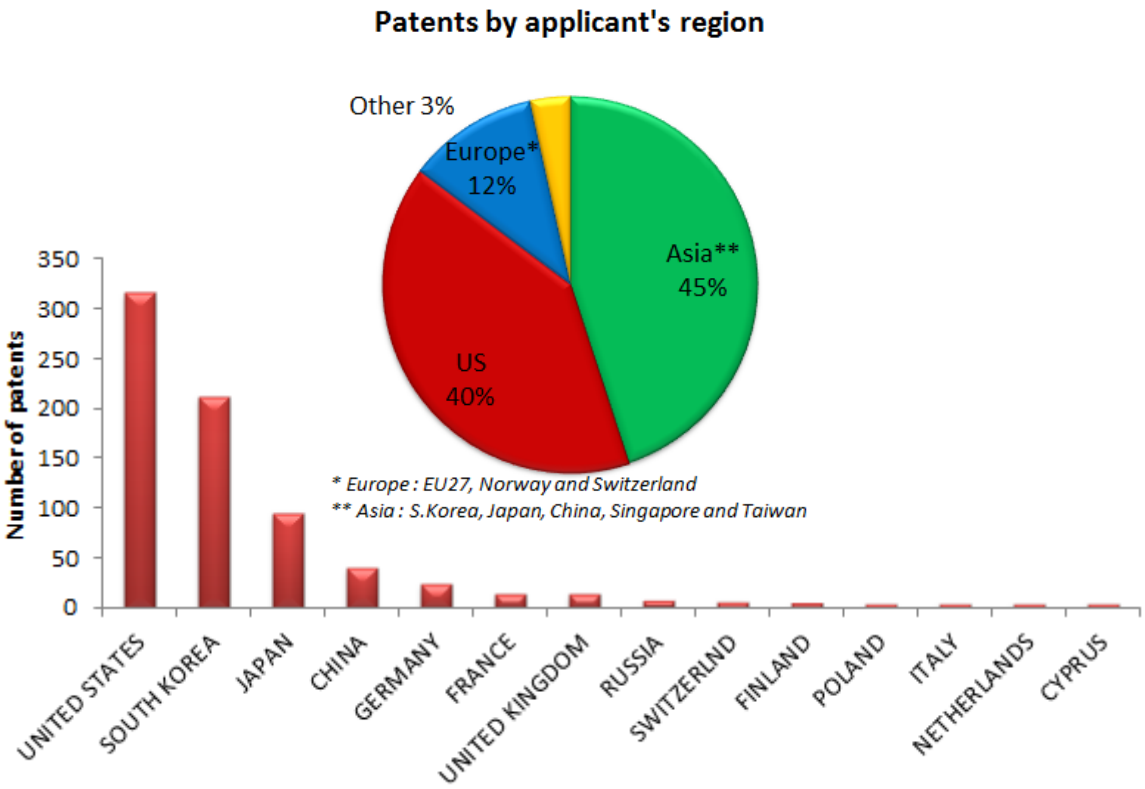


Figure 2.13 Share of graphene-related patents per world region (top) and number of patents per country (bottom). Source : European Patents Office Worldwide database, September 2011.

A detailed report on "Graphene Key Patent Analysis" was published in February 2011 by Displaybank taking into account data registered until 20 August 2010[10]. The report analyses patent application trends, major regions working on graphene, and graphene patent applicants. Statistical data are presented per region (Europe, U.S., Korea and Japan), manufacturing technology and field of application (energy, displays, electronic devices and composite materials).

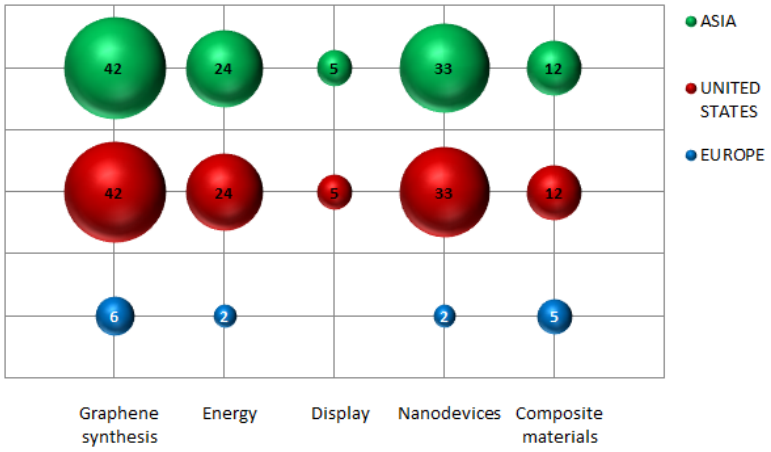


Figure 2.14 Patent application by technology and country. Source: adapted from "Graphene Key Patent Analysis" by Displaybank, February 2011.

[10] http://www.displaybank.com/letter_2010/letter3346.htm

3 Industrial Activity

The information on funding of industrial activities in the field of graphene science and technology is not readily available due confidentiality and strategic reasons. This section provides a short overview of the Pilot's actions towards the active involvement of industry in the Flagship proposal. The Graphene-CA Pilot has organized a dedicated workshop on "Graphene for Future and Emerging Technologies'" held in Madrid on the 18 October 2011 gathering European, Asian and US industrial representatives to discuss current involvement and future interest in developing graphene-based technologies. The workshop was attended by over 60 industries and gathered about 200 participants.
Based on the information collected at this workshop and the information provided by the national representatives, there are about 100 industries potentially interested in graphene-related technologies. A non-exhaustive list of these companies is provided in Annex C.

The areas of applications for graphene-based products are broad and include:

- Transparent and flexible electronics, optoelectronics, microelectronics and photovoltaics
- Chemicals, inks and coatings
- Composite materials for enhanced structural and mechanical properties
- Energy applications : batteries and supercapacitors
- Health and pharmaceuticals

In all of these fields of application, graphene may provide advantages over existing technologies, provided that ***sufficient amounts*** of material are available ***at low costs***. The production of graphene by top down or bottom up approaches has been widely addressed as one of the key aspects for future development of graphene-based technologies.
Several SMEs are currently producing graphene with different material properties and significant activities are registered in UK, Spain, Germany, Norway and other countries. The materials specifications and quality is strongly dependent on the final applications and ***standardized characterisation tools and procedures*** will be needed in the future.

4 Future Initiatives

During the preparation of this report, a number of new initiatives has been announced in several countries (United Kingdom, Sweden, and Denmark) and have been included in the previous analysis on future funding. In other countries, national representatives have reported on the preparation of initiatives that are planned or under evaluation. These are summarized in the table below. More details can be found in the corresponding summaries per country in Annex B.

Country	Initiative	Status	Budget
Austria	*FWF Special Research Focus (SFB) "Materials design of graphene"*	Submitted	800 k€/year for 8 years
France	*Equipex national project - platform focused on the synthesis of graphene (SMARTPHENE)*	Submitted	5 M€
Greece	*FORTH Graphene Center*	To be launched	100 k€
Hungary	*R&D programme in the field of graphene research – application to the Hungarian fundamental Research Fund*	Planned to be launched in 2012	N/A
Netherlands	*STW proposal on "Graphene Technology and Applications"*	Submitted	2.8 M€
Norway	*Norwegian Research Council new programme in nanotechnology and new materials –funding of graphene research as part of it*	To be launched	N/A
Poland	*National programme in the area of graphene technology and applications*	In preparation	N/A
Romania	*Research Center for Integrated Systems Nanotechnologies and Carbon Based Nanomaterials (CENASIC)*	To be launched in 2014	600 k€ - EU Structural funds

Table 4.1 Overview of future and planned initiatives in the field of graphene

5 Conclusions

The aim of this report and the information provided by the national representatives in the Annexes is to provide a first basis for the preparation of the financial plan for the Flagship proposal. The results gathered through the various sources allow obtaining an insight into the current investments at the national and European level taking into account the limitations and availability of data. The main part of this document addressed the public funding of research projects and programmes at the national level and a comparison with the current support from the EU.

As new initiatives and programmes are expected in the near future, it will be necessary to constantly monitor and inform the relevant stakeholders throughout the process of the preparation of the Flagship proposal. The same stands for investments by the private sector which has shown strong interest but for which reliable data on investments could not be presented.

The analysis of the scientific output showed that Europe leads in terms of scientific excellence but lags behind Asia and US concerning patenting activity. This phenomenon is well-recognized and represents an important issue to be addressed in the development of the Flagship programme and in particular the IP aspects of it.

The figures and the trends observed, namely the current level of national funding and the foreseen launching of new national initiatives in several countries, combined with the additional funds from the EC expected to be available through the Flagship programme, indicate that the Graphene Flagship would be sustainable during the ramp-up phase to begin in 2013. The preparation of the second phase under Horizon 2020 will require additional long-term planning and insight into the instruments and budgets both at the national and EC level.

Annex A : European Commission projects

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
1	New Electronics Concept: Wafer Scale Epitaxial Graphene	CONceptGraphene	2010	2013	3230	Collaborative Research-ICT
2	Source of Electron Entanglement in Nano Devices	SE2ND	2011	2014	2480	Collaborative Research-ICT
3	Graphene based nanoelectronic devices	GRAND	2008	2011	2390	Collaborative Research-ICT
4	Terascale reliable adaptive memory systems	TRAMS	2010	2013	2450	Collaborative Research-ICT
5	Strongly anisotropic Graphite-like semiconductor/dielectric 2D nanolattices	2D-NANOLATTICES	2011	2014	1630	Collaborative Research-ICT
6	Suspended Graphene Nanostructures	RODIN	2010	2013	2890	Collaborative research-NMP
7	GRaphenE for NAnoscaleD Applications	GRENADA	2011	2014	3450	Collaborative Research-NMP
8	Large area fabrication of 3D Negative Index Materials by Nanoimprinting Lithography	NIM_NIL	2009	2012	3370	Collaborative Research-NMP
9	Graphene-based Electrodes for Application in Supercapacitors	Electrograph	2011	2014	3580	Collaborative research-NMP
10	Thermal management with carbon nanotube architectures	THEMA-CNT	2009	2012	2530	Collaborative research-NMP

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
11	High Aspect Ratio Carbon-based Nanocomposites	HARCANA	2008	2012	5440	Collaborative research-NMP
12	Development of high energy/high power density supercapacitors for automotive applications	AUTOSUPERCAP	2011	2014	3970	Collaborative research-NMP
13	Graphene Flagship Pilot Action	Graphene CA	2011	2012	1450	Coordination Action
14	How to Control Graphene	HOWTOCONTROLGRAPHENE	2009	2014	1564	ERC-AdG
15	The Chemists Way of Making and Utilizing Perfect Graphenes	Nanograph	2011	2016	2500	ERC-AdG
16	Large Scale Production, Cloning, Chemical Functionalization and Materials Applications of Graphene	GRAPHENOCHEM	2010	2015	1436	ERC-AdG
17	In-situ NanoElectrical Measurements in a Transmission Electron Microscope	NEMINTEM	2011	2016	2500	ERC-AdG
18	Quantitative Multidimensional Imaging of Interfacial Fluxes	QUANTIF	2010	2015	2129	ERC-AdG
19	Mesoscopic quantum noise: from few electron statistics to shot noise based photon detection	MEQUANO	2009	2014	2000	ERC-AdG
20	Physical and Analytical Chemical sciences	SCIFRI	2011	2016	2490	ERC-AdG
21	Electronic devices based on nanolayers	FLATRONICS	2009	2014	1800	ERC-StG

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
22	Complex molecular-scale systems for NanoElectronics and NanoPlasmonics	COMOSYEL	2008	2013	1440	ERC-StG
23	Understanding the electronic properties of carbon nanotubes and graphene as quantum conductors	NANO-GRAPHENE	2011	2016	1040	ERC-StG
24	ERC Starting Grant: Spin dynamics and transport at the quantum edge in novel nanostructural materials	SYLO	2010	2015	1230	ERC-StG
25	Physics and applications of graphene	GRAPHENE	2008	2013	1775	ERC-StG
26	Characterizing and Controlling Carbon Nanomaterials	CCCAN	2010	2015	1469	ERC-StG
27	A Universal Supramolecular Approach toward Organic Electronic Materials and Nanostructured Carbonaceous Materials from Molecular Precursors	ORGELNANOCARBMATER	2009	2014	1700	ERC-StG
28	High performance and ultralight carbon nanotube wires for power transmission	HPCNTW	2010	2015	1470	ERC-StG
29	Quantum Monte-Carlo in mesoscopic devices	MESOQMC	2011	2016	1222	ERC-StG
30	A Research Platform Addressing Outstanding Research Challenges for Nanoscale Design and Engineering of Multifunctional Material	MULTIMATE	2010	2015	1485	ERC-StG
31	Exfoliation of Inorganic Layered Compounds	SEMANTICS	2010	2015	1410	ERC-StG
32	In-situ metrology for the controlled growth and interfacing of nanomaterials	INSITUNANO	2011	2016	1370	ERC-StG

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
33	Graphene Nano-photonics	GRANOP	2011	2014	100	Marie Curie-CIG
34	Exotic quantum phases in graphene and other modern nanomaterials - physical foundation for quantum information technology	EXOTICPHASES4QIT	2011	2015	100	Marie Curie-CIG
35	Unique Nanocarbons from Critically Opalescent Solutions	UNCOS	2010	2014	550	Marie Curie-IAPP
36	High-throughput development of carbon-polymer nanocomposites for marine applications	CARBONCOMP	2011	2015	1540	Marie Curie-IAPP
37	Intercalated Graphene Carbon Nanotubes for Heterogeneous Catalysis	GRAPH-CNTS-CAT	2010	2011	82	Marie Curie-IEF
38	Adaptive nanostructures prepared by hierarchical self-assembly	ADAPTNANO	2010	2012	169	Marie Curie-IEF
39	Mechanical Amplification in Carbon-based NanoElectroMechanical Systems	MACNEMS	2011	2013	173	Marie Curie-IEF
40	Quantum Interference and electro-PHonon ANOmalies in graphenes	QUANTUMPHANOGRAPHENE	2011	2013	206	Marie Curie-IEF
41	Theoretical study of electronic transport in carbon nanostructures and molecular wires	NANOTRAN	2008	2010	161	Marie Curie-IEF
42	Opto-electronic properties of graphene and other carbon nanostructures	CARBOTRONICS	2008	2010	234	Marie Curie-IEF
43	Advanced methods for the removal and monitoring of polar organic contaminants	POLARCLEAN	2011	2013	200	Marie Curie-IEF

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
44	Visualising Electrocatalysis at the Nanoscale	VISELCAT	N/A	N/A	N/A	Marie Curie-IEF
45	Magneto-optics of carbon nano-allotropes	MOCNA	2009	2011	233	Marie Curie-IEF
46	pi-Electronic Gel Hybrids: Towards Smart Photoactive Nanomaterials	GELBRID	2011	2013	189	Marie Curie-IIF
47	Graphene-Based Ultra-Sensitive Gas Sensors	GRAPHENEGASSENSORS	N/A	N/A	N/A	Marie Curie-IIF
48	Novel kind of graphene based materials and its blend with polythiophenes	GRAPHENETHIOPHENE	2009	2011	167	Marie Curie-IIF
49	Image supramolecular binding processes on the molecular level by STM for fundamental understanding sensor	SEE 2 SENSE	2011	2013	234	Marie Curie-IOF
50	Terahertz applications of carbon-based nanostructures	TERACAN	2009	2013	0	Marie Curie-IRSES
51	New Century of Superconductivity: Ideas, Materials, Technologies	SIMTECH	2010	2014	713	Marie Curie-IRSES
52	GraphenE-orgaNIc hybrid architectures for organic electronics: a mUltiSite training action	GENIUS	2010	2014	4322	Marie Curie-ITN
53	Nanoelectronics: Concepts, Theory and Modelling	NANOCTM	2009	2013	2466	Marie Curie-ITN
54	SUPramolEculaR functional nanoscale architectures for Organic electronics: a multi-site initial tRaining action	SUPERIOR	2009	2013	4000	Marie Curie-ITN

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
55	Ultra-sensitive chemical detectors based on graphene nanoribbons	GNRSense	2010	2014	100	Marie Curie-RG
56	Electronic correlation in pristine and doped graphene layers	ECO-GRAPHENE	2009	2012	45	Marie Curie-RG
57	Bismuth and Graphene Nanostructures for Spintronics	BIGNSPIN	2010	2013	45	Marie Curie-RG
58	Graphene Based Radio Frequency Electronics	GRAPHENERF	2010	2014	100	Marie Curie-RG
59	Carbon-based nanoelectronics	CARBOTRON	2011	2014	45	Marie Curie-RG
60	Advanced optoelectronic materials through dynamic combinatorial assembly	OPTOELECTRONIC_DCA	2009	2012	45	Marie Curie-RG
61	DOTUBE: Interactions between semiconductor nanoparticles and carbon nanotubes	DOTUBE	2009	2012	45	Marie Curie-RG
62	Quantum Nano Optomechanics	QNAO	2010	2013	45	Marie Curie-RG
63	Carbon nanotube networks for electronics applications	CANNELA	2009	2012	45	Marie Curie-RG
64	Investigation of the electronic properties of nanostructures at the atomic scale by means of low temperature scanning tunneling microscopy/spectroscopy in ultrahigh vacuum conditions	STSON	2009	2012	45	Marie Curie-RG

	Title	Acronym (title)	Start	End	Total Funding (k€)	Type of Project
65	Enabling ultimate metrological quantum Hall effect (QHE) devices	ULQHE	2008	2011	336	Other-EMRP
66	Graphene Chemical Vapour Deposition : roll to roll technology	GRAFOL	2011	2014	NA	Other-FoF
			Total funding (k€)		**87625**	

Annex B: National funding per country

In this annex the data are presented per country according to a pre-defined template. The different fields have been filled with available information as follows:

- The ***summary on scientific activities, industrial activity, research infrastructures and future activities*** has been provided by national representatives for each country.

- The ***scientific output*** (number of publications) was extracted from the online publications databases by the national representatives

- Information on ***patents*** was collected by the ESF through the European Patent Office portal Worldwide database (http://worldwide.espacenet.com, data extracted on 7/09/2011) by using “graphene” as a keyword.

- The list of ***research institutes*** was made by combining the information received through the web portal, the national funding agencies and national representatives. Some of the organisations listed, although may not have received funding specifically for graphene research, have expressed interest or are working on the topic using other sources of funding.

- The number of ***Principal Investigators (PIs)*** was estimated by cross referencing the information on research projects and the institutions that were submitted through the web portal or provided by the national agencies.

- The figures on ***research funding*** were estimated by the ESF by taking into account:

    - The total number of PIs as a sum of the total number of PIs per institution
    - The total number of active research groups as registered on the web portal
    - The total funding for the year 2011 was calculated taking into account the funding and duration of the research projects as provided by the funding organisations, the national representatives, and the researchers. This amount includes the national research funding from public sources only and takes into account projects for which the relevance to graphene research could be identified and confirmed. Personnel costs and permanent salaries are not included unless they are part of the research projects.

Country	Flag	Acronym	Web registrations (15 Oct 2011)	Funding agency data	Nat.Rep.Summary	Total current public research funding (M€)	Future funding (M€) Expected/announced	Comments
Austria		AT	6	Yes (FWF)*	Yes	1.3		
Belgium		BE	10	Yes (FNRS)	Yes	4.0		
Bulgaria		BG	N/A	No	No	N/A		
Croatia		HR	1	No	No	0.2		
Cyprus		CY	2	No	Yes	N/A		
Czech Republic		CZ	4	Yes (GACR)	No	0.1		
Denmark		DK	7	Yes (DFF)	No	2.3	7.2	
Estonia		EE	1	No	Yes	0.7		
Finland		FI	10	Yes (AKA)	Yes	3.5		
France		FR	70	No	Yes	21.4		Includes 6,5 M€ CEA overall funding
Germany		DE	40	Yes (DFG, BMBF)	Yes	38.7		
Greece		GR	13	No	Yes	0.8		
Hungary		HU	11	Yes (OTKA)	Yes	0.6		
Ireland		IE	4	No	Yes	2.8		
Israel		IL	18	No	Yes	0.9		
Italy		IT	44	No	Yes	3.2		
Latvia		LV	1	No	Yes	0.2		
Lithuania		LT	N/A	No	No	N/A		
Luxembourg		LU	N/A	No	No	N/A		
Malta		MT	N/A	No	No	N/A		
Netherlands		NL	23	Yes (FOM, STW)	Yes	8.0		
Norway		NO	1	No	No	0.3		
Poland		PL	34	No	Yes	2.0		
Portugal		PT	8	Yes (FCT)	No	0.8		
Romania		RO	3	No	Yes	0.3		
Serbia		SRB	1	No	No	0.1		
Slovakia		SK	1	No	No	N/A		
Slovenia		SI	2	No	No	0.2		
Spain		ES	100	No	Yes	2.5		Underestimate
Sweden		SE	16	Yes (VR)*	No	7.5	4.4	
Switzerland		CH	8	Yes (SNF)*	Yes	14.2		
Turkey		TR	1	No	No	0.2		
United Kingdom		UK	51	Yes (EPSRC)	Yes	38.2	57.0	
TOTAL			491			**154.6**	**68.6**	
* Online project database								

AUSTRIA

Country	Austria
Contact (name, email)	Jannik Meyer, Jannik.Meyer@univie.ac.at
Organisation	University of Vienna, Department of Physics

Summary of scientific activities and funding

Research groups in Austria comprise leading-edge expertise in **Microscopic and Spectroscopic Characterisation** (J. Meyer, U. Diebold, T. Pichler), **High-frequency devices and photonics** (Th. Müller, K. Unterrainer), **Fabrication and Structuring** methods of graphene (I. Bergmair) and new aspects in the **Theoretical description** of graphene (J. Burgdoerfer, F. Libisch, C. Ambrosch-Draxl, S. Selberherr, H. Kosina, J. Redinger).

Microscopic and spectroscopic characterisation:

- At the University of Vienna (UVIE), **T. Pichlers** research group has established an excellent background on the Ultra-high vacuum (UHV) synthesis and functionalization of quasifreestanding graphene on metal surfaces, and gained a profound knowledge on the fundamental electronic and optical properties using high energy spectroscopy with energy and momentum resolution. Co-PIs (postdocs) in the group include C. Kramberger, A. Grüneis, amd P. Ayala.
- At the Technical University of Vienna (TUVIE), **U. Diebold** is an internationally recognized expert in the area of surface chemistry and she has recently started to investigate the (defect) structure of CVD-grown graphene layers on Ni(111) .
- **J. C. Meyer** was recently (September 2010) appointed as new professor in the Department of Physics at UVIE. He is currently in the process of setting up a new research lab. He is well known for pioneering work on the microscopic characterization of graphene and related materials.

Relevance for the flagship project: The microscopic and spectroscopic characterization team can play a key role to establish the connection between structural modifications in graphene, and their effect on the electronic, mechanical, optical, chemical and other properties. A large synergy on this topic is expected from E.U.-wide collaborations; e.g. with groups that have an expertise on synthesis or other characterization

methods.

High-frequency devices and photonics

- At TUVIE's Institute of Photonics, **Th. Müller** and **K. Unterrainer** have established a research focus on graphene's properties in the terahertz spectral regime, picosecond carrier dynamics in graphene, and the application to ultra-high speed electronic and photonic devices. The expertise covers all aspects of modern photonics, including new approaches such as the on-chip terahertz generation and detection. Co-PIs include A. Urich, M Furchi, and A. Pospischil.

Relevance for the flagship project: The operation of ultrafast graphene-based electronics and optoelectronics will depend on our ability to probe and understand its properties in the range between 0.1 and 10 THz. With a long-standing research idea to close the technological gap between high frequency electronics and photonics, the Institute of Photonics is ideally set up for this task.

Theoretical description

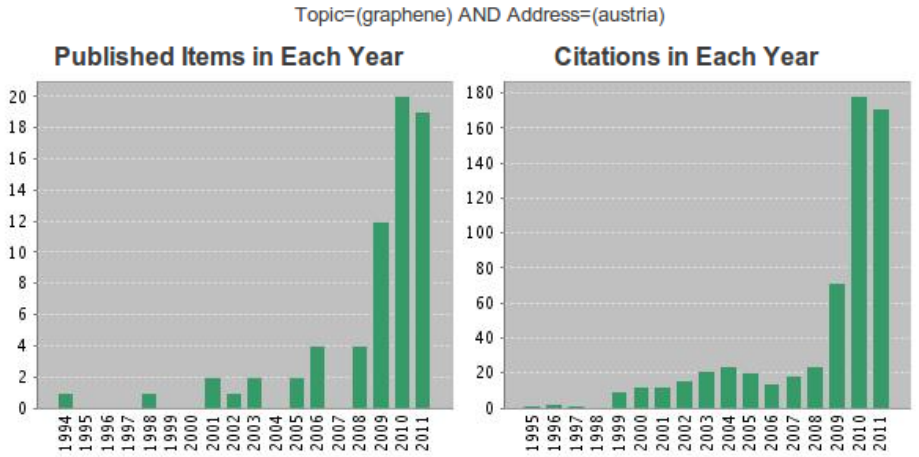
- At TUVIE, **J. Burgdörfer** and **F. Libisch** are well known experts for the simulation of large-scale electronic structures and transport through nanodevices, including graphene, semiconductors, SN-hybrid structures and microwave resonators. Simulations of eigenstates of graphene quantum dots have predicted characteristic features meanwhile observed in experiments and have been used to accurately pin down the electron-hole crossover point [PRL 103, 046810 (2009)].
- At the University of Leoben, the research of **C. Ambrosch-Draxl** is mainly focused on the interface of graphene and related materials with molecules. We study the bonding as well as electronic and optical properties of such interfaces, analyzing and trying to understand the interactions between the two sides, which are often of many-body nature (e.g. change of band-gap and optical excitations compared to the pristine materials) . The methodology we use is density-functional theory (DFT), time-dependent DFT, and many-body perturbation theory [PRB **80**, 235431 (2009)].
- At TUVIE, **S. Selberherr** and **H. Kosina** explore Electrical and Optoelectrical Graphene Devices as part of a joint project aiming at the development of graphene-based field-effect-transistors (FETs) and photodetectors, their quantitative characterization, and physical

modeling.

- Also at TUVIE, **J. Redinger** and **F. Mittendorfer** work within the ESF "Spingraph" project to study magnetic interactions at the graphene/3d metal interface using DFT and post-DFT (RPA) approaches.

Relevance for the flagship project: Due to the rich chemistry of carbon, and the variety of interactions in graphene-related materials, modeling is often not straightforward. Our work will help to elucidate the chemistry of defects, electronic structure modifications by functionalization, or the interface to physisorbed molecules on graphene.

Scientific output
Publications :
(h-index of graphene research in Austria: 13) :



Patents	
Applicants	0

Inventors	1
Research institutes / Number of PIs	
University of Leoben	1
University of Vienna	2
Vienna University of Technology	4
Research funding	
Total number of PIs	7
Total number of active research groups*	7
National research funding per year for 2011 (in k€)	251
SMEs and Industrial R&D activity	
The group Functional Surfaces and Nanostructurs at PROFACTOR GmbH (Contact: Iris Bergmair) coordinates the national ”NILgraphene” project and the FP7 project ”NIM_NIL”. Within these projects PRO gathered experiences in structuring and exfoliation of structured graphene using Nanoimprint Lithography and Photolithography. These methods offer the possibility to achieve structured graphene in the µm as well as nm regime down to 20 nm for applications like graphene based transistors and photodetectors. PROFACTOR has experiences not only in structuring techniques like NIL but also in sol-gel technology and characterisation methods like AFM, MFM, contact angle measurements and ellipsometry.	
Research Infrastructures	
T. Pichlers research group is using high energy spectroscopy with energy and momentum resolution (EELS, XPS, resonant and angle resolved photoemission (RESPES, ARPES and XAS). U. Diebolds lab houses four UHV chambers with STM’s with different capabilities (RT, 4K, variable-temperature/fast-scanning). J. C. Meyer is currently in the process of setting up a research lab, including a state of the art aberration-corrected transmission electron microscope.	

* *Only data submitted via web portal www.graphene-flagship.eu*

Th. Müller and K. Unterrainer employ state of the art infrastructure for semiconductor device fabrication (MBEs, SEM, e-beam-, contact- and laser-lithography, AFM/STM, XRD, FIB, ALD, ion milling, RIE, PECVD, sputtering, metallization, wafer bonding, wire bonding, and many more) in a cleanroom.
Future activities
An application for a special research focus (SFB) with the title ”Materials design of graphene” has been submitted to the national funding agency (FWF) by the groups of J. Meyer, T. Pichler, U. Diebold, T. Müller, W. Lang, F. Libisch, S. Sariciftci and C. Ambrosch-Draxl. In case of a positive funding decision, the project would start in 2013, last for 8 years (review after 4 years), and have a budget of ca. 800.000 Euro per year. The aim of the project is to achieve atomistic control on the structure as well as the electronic transport properties of graphene systems through a concerted effort and intimate connection between the controlled preparation of functional groups, dopants, or other defects in our target materials; cutting-edge microscopic and spectroscopic techniques, and analysis of the effect of the modification on application-relevant parameters (electronic transport, optical properties), along with theoretical analysis.

BELGIUM

Country	BELGIUM
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Organisation	University of Louvain (UCL), 1348 Louvain-la-Neuve, Belgium University of Antwerp (UA), 2020 Antwerp, Belgium

Summary of scientific activities and funding

Prof. J.-C. Charlier has investigated using *ab initio* calculations, the quantum transport properties of disordered graphene (containing point defects such as Stone-Wales and divacancies) in order to predict the crucial role played by these scattering centers in « real » graphene samples. His theoretical results suggested that the Anderson localization regime could be experimentally measurable for a defect density as low as 1% [1]. In addition, 1D extended lines of structural defects (as recently observed by STM) exhibit localized states along the line and behave like metallic wires embedded in graphene sheets, suggesting their possible role as reactive tracks to anchor molecules or atoms for chemical or sensing applications or in future electronic graphene-based nano-devices [2].

Focusing on systems that can be experimentally realized with existing techniques, both in-plane conductance in interconnected graphene nanoribbons and tunneling conductance in out-of-plane nanoribbon intersections were investigated using *ab initio* calculations [3]. Both simulations confirmed the possibility of designing graphene nanoribbon-based networks capable of guiding electrons along desired predetermined paths. The stacking angle between individual sheets was found to play a central role in dictating the electronic transmission probability within the networks.

The tuning of graphene electronic properties by chemical functionalization has also opened a new era of solid-state electronics. Using a multiscale ab initio approach, he has studied the electronic and the transport properties of graphene after epoxide functionalization via ozone treatment. The orbital rehybridization induced by the epoxide groups was found to trigger a strong intervalley scattering and to change dramatically the conduction properties of graphene. By varying the coverage density of epoxide defects from 0.1 to 4%, charge conduction was tuned from a diffusive to a strongly localized regime, with localization lengths down to a few nanometers long. Experimental results supporting the interpretation as a metal-insulator transition was also provided [4].

At last, spin-dependent features in the conductivity of graphene, chemically modified by a random distribution of hydrogen adatoms, were explored theoretically. Using spin-polarized *ab initio* calculations, magnetoresistance signals up to ~7% were calculated for hydrogen densities around 0.25%. These important theoretical predictions of Prof. J.-C. Charlier could serve as guidance for experimental observation of induced magnetism in graphene [5-6].

Prof. Jean-Christophe Charlier is presently Full Professor of Physics at the Ecole Polytechnique de Louvain in UCL. He has authored or co-authored more than 110 scientific publications in high-level international peer-reviewed journals (such as Nature, Science, Reviews of Modern

Physics, Phys. Rev. Lett., PNAS, Nano Lett., ACS Nano, Phys. Rev. B, Appl. Phys. Lett., Carbon, etc.) and has more than 6600 independent citations to his work (*h*-index 46).

[1] A. Lherbier, *et al.* Phys. Rev. Lett. 106, 046803 (2011).
[2] A.R. Botello-Mendez, *et al.* Nanoscale 3, 1008 (2011).
[3] A.R. Botello-Mendez, *et al.* Nano Letters 11, 3058 (2011).
[4] N. Leconte, *et al.* ACS Nano 4, 4033 (2010).
[5-6] N. Leconte, *et al.* ACS Nano 5, 3987 (2011) ; Phys. Rev. Lett. 107, 016602 (2011).

In Belgium, Graphene research can be financed as :

- individual projects (National Fund for Scientific Research of Belgium _ F.R.S.-FNRS ;
"Research Concerted Action" sponsored by the Communauté Française de Belgique ;
more applied research financed by the Walloon Region ;
or even by the local Universityin the form of "Special Research Funds")
- coordinated networks five-year fundamental research projects, issued by the Belgian federal science policy office http://www.belspo.be/iap/. The call is for research programs that involve universities from the Flemish as well as the Walloon region of Belgium, with the option of including up to four international partners.

International Collaborations

- Catalan Institute of Nanotechnol (ICN-CSIC, Barcelona, Spain)
- ONERA - CNRS (Paris, France)
- Institut Néel CNRS (Grenoble, France)
- Cambridge University (Cambridge, UK)
- Massachussets Institute of Technology (Cambridge, USA)
- Renselear Polytechnic Institute (New-York, USA)
- PennState University (USA)
- Rice University (Texas, USA)

The research group of **Prof. F.M. Peeters** investigated the electronic and optical properties of single and bilayer graphene nanostructures. In particular graphene quantum dots and rings were studied using the *tight binding* approach and the *continuum Dirac-Weyl* equation. We showed that both zigzag and armchair edged hexagonal graphene quantum dots exhibit an energy gap which has subsequently been confirmed experimentally. Using nanostructured gates we showed theoretically [1] that it is possible to realize quantum dots and rings in bilayer graphene where electron and hole states are electrostatically confined. The magnetic field and angular momentum dependence of the energy levels was found to be strikingly distinct from that of conventional semiconductor dots and rings.

Motivated by the experimental realization of graphene sensors to detect individual gas molecules we used *ab initio* calculations to investigate the adsorption energy and charge transfer between different molecules and the graphene substrate [2]. The efficiency of doping of the different molecules was determined and the influence of their magnetic moment was critically examined. Functionalization of graphene with hydrogen and fluor was studied where experimental quantities as the energy gap, the phonon spectrum and the Young's modulus are determined. We also showed that patterned hydrogenation of graphene is a promising way to obtain stable graphene nanoribbons with interesting technological applications. The penetration of molecules through a graphene monolayer containing defects was studied using similar techniques. We demonstrated that very large defects are needed to make the graphene sheet permeable for atoms and molecules. This makes graphene a very promising material for the construction of nanocages and nanomembranes [3].

Atomistic simulations were carried out to determine the lowest energy configurations of nanographene clusters. The frozen in topological defects that are present and the type of edges were found for different sizes of nanographene. The mechanical properties are investigated were the response of the graphene membrane on different types of local stresses are calculated in the presence of grain boundaries and other defects. Strain engineering is proposed as a possible route to modify the electronic properties of graphene.

Prof. Francois Peeters is presently full professor at the Universiteit Antwerpen (UA). He has authored or co-authored more than 900 scientific publications in high-level international peer-reviewed journals (such as Nature, Nano Letters, Physical Review Letters, Applied Physics Letters, etc.) and has more than 15000 citations with h-index 58.

[1] J.M. Pereira *et al*, Nano Lett. **7**, 946 (2007); M. Zarenia *et al*, Nano Lett. **9**, 4088 (2009).
[2] O. Leenaerts *et al,* Phys. Rev. B **77**, 125416 (2008).

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Funding programmes

In Flanders (Belgium) graphene research can be financed through:

- Flemish Science Foundation (FWO-Vl)
- Agency for Innovation by Science and Technology (IWT)
- Bijzonder Onderzoeks Fonds van de Universiteit Antwerpen (BOF/UA)

On the Federal level:

- Belgian Science Policy Office (BELSPO) who funds five year Interuniversity Attraction Poles (IAP) networks on fundamental science.

International Collaborations

- ETH (Zurich, Zwitserland)
- University of Konstanz (Konstanz, Germany)
- Delft University of Technology (Delft, The Netherlands)
- University of Dusseldorf (Dusseldorf, Germany)
- National Research Council (NRC, Ottawa, Canada)
- Concordia University (Montreal, Canada)
- Chinese Academy of Sciences (Hefei, China)
- Yerevan State University (Yerevan, Armenia)
- Jilin University (Changchun, China)
- Nanjing University (Nanjing, China)
- Centro Atomico Bariloche (San Carlos de Bariloche, Argentina)
- Semiconductor Physics Institute (Vilnius, Lithuania)
- National University of Uzbekistan (Tashkent, Uzbekistan)
- Universidade Federal do Ceara (Fortaleza, Brazil)
- Shahid Rajaee Teacher Training University (Tehran, Iran)

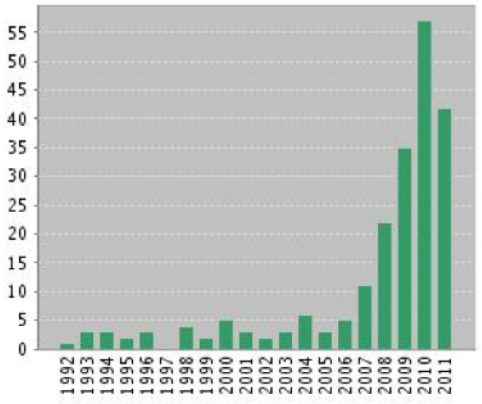
Scientific output	
Publications :	

Citation Report Topic=(graphene) AND Address=(belgium)

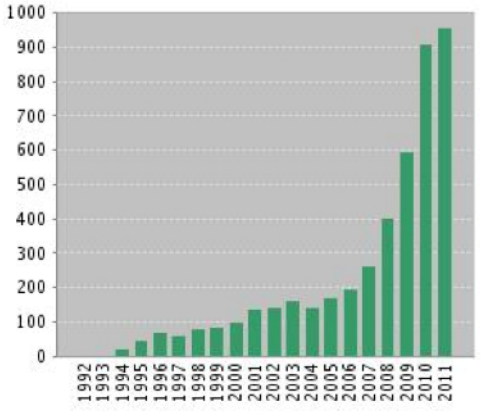
Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI.

This report reflects citations to source items indexed within Web of Science. Perform a Cited Reference Search to include citations to items not indexed within Web of Science.

Published Items in Each Year



Citations in Each Year



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Sum of the Times Cited [?] : 4521

Sum of Times Cited without self-citations [?] : 4223

Citing Articles[?] : 3494

View Citing Articles
View without self-citations

Average Citations per Item [?] : 21.33

h-index [?] : 34

Patents	
Applicants	3
Inventors	4
Research institutes / Number of PIs	
Catholic University of Leuven	2
University of Antwerp	2
University of Mons	2
University of Namur	1
Research funding	
Total number of PIs	7

Total number of active research groups*	10
National research funding per year for 2011 (in k€)	787

SMEs and Industrial R&D activity

(1) ***Nanocyl*** *(*Rue de l'Essor, 4 B-5060 Sambreville BELGIUM)
Nanocyl provides high-quality **Carbon Nanotube** (CNT) and **Graphene** technologies that can improve the properties of your plastic and composite applications. Our carbon nanotubes are tailor-made for ESD/electrical conductivity, thermal protection, eco-friendly anti-fouling, and mechanical reinforcement.

(2) ***AGC Flat Glass*** (Chaussee de La Hulpe 166, 1170 Brussels, BELGIUM)
AGC Flat Glass produces and processes flat glass for the construction industry (exterior glazing and interior decor) and for specialized industries (transport, electric domestic appliances, high-tech, etc.). It is the European branch of AGC (Asahi Glass Company) Flat Glass, the world's leading producer of flat glass. Its products, which are the result of cutting edge R&D, are marketed around the whole world.

(3) ***SOLVAY*** (rue de Ransbeek, 310 - B-1120 Brussels, BELGIUM)
Solvay is an international industrial Group, active in chemicals & plastics, with a strong focus on new sustainable products

(4) ***IMEC*** (Kapeldreef 75, 3001 Leuven, BELGIUM)
Imec performs world-leading research in nano-electronics and nano-technology. Its staff of more than 1,900 people includes over 500 industrial residents and guest researchers. Imec's research is applied in better healthcare, smart electronics, sustainable energy, and safer transport.

Research Infrastructures

Research Infrastructures :

- Prof. Jean-Christophe Charlier and Dr. Annick Loiseau (ONERA – CNRS) are co-coordinating the International network GDRI GNT 'Graphene and Nanotubes: Sciences and Application' (http://www.graphene-nanotubes.org/) with Dr. Annick Loiseau (ONERA – CNRS). The GDRI has been created by the DRIE, Office of European Affairs and International Relations of the CNRS on 1st january 2009 for four years.

- International Doctoral School in Functional Materials for Energy, Information Technology and Health (IDS-FunMat)

- Prof. Jean-Christophe Charlier and two colleagues (Profs. Xavier Gonze and Gian-Marco Rignanese) form the UCL node of the European Theoretical Specroscopy Facility (ETSF). The ETSF is a distributed knowledge centre carrying out state-of-the-art research on theoretical and computational methods for studying electronic and optical properties of materials, and offers its expertise to researchers, industry, and students in

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the form of collaborative projects, free scientific software, and training (http://www.etsf.eu). The ETSF gathers the experience and know-how of more than 200 researchers in Europe and the United States.
The ETSF is based on a Memorandum of Agreement approved by the 10 core institutions, in September 2010, for four years. UCL is the central node of the facility and host its President (X. Gonze) and Chief Executive. The core node partners are : Ecole polytechnique Palaiseau (France), U. Basque Country, San Sebastian (Spain), U. York (UK), Fritz-Haber-Institute der Max-Planck Gesellshaft, Berlin (Germany), U. Lund (Sweden), U. Milano (Italy), U. Rome Tor Vergata (Italy), Max-Planck-Institute Halle (Germany), U. Jena (Germany)

- At Universiteit Antwerpen: available computer infrastructure: cluster SEASTAR with 246 cores, 650 GB RAM and 18 TB storage; cluster TURING cluster with 768 cores and 25 TB storage.
- At KUL (Leuven): atomic force microscopy (1.5 – 300K; 0 – 2 Tesla); scanning tunnelling microscopy in UHV (5 – 300K); magnetotransport measurements down to 300 mK and up to 17 Tesla; MBE growth with in situ ion-beam implantation and irradiation; electron-beam and optical lithography.
- At UH (Hasselt): scanning electron microscope with e-beam writing facility; XPS; EELS; magnetotransport setup.

Future activities

- Research Concerted Action sponsored by the *Communauté Française de Belgique*
  "*Graphene Nano-electromechanics – Stresstronics at UCL*" (Total 1.100.000 €)
  Convention N° 11/16-037 - duration : 01/09/2011 – 31/08/2016
  (Profs J.-C. Charlier, B. Hackens, T. Pardoen, and JP Raskin)

- Research Concerted Action sponsored by the *Communauté Française de Belgique*
  "Hybrid metal/organic Nanosystems" at UCL (Total 1.020.000€)
  Convention N° 07/12-003 - duration : 01/09/2007 – 31/08/2012
  (Profs J.-.C Charlier, X. Gonze, L. Piraux, and G.-M. Rignanese)

Belgium Interuniversity Attraction Pole on « Quantum Effects in Clusters and Nanowires »
PAI- IUAP P6/42 (2007-2011) - duration : 01/01/2007 – 31/12/2011 - (Total 1.200.000 €)
(Promoters V. Bayot, J.-.C Charlier, X. Gonze, S. Melinte, L. Piraux, and G.-M. Rignanese)

- FRFC Project funded by the FNRS
  Développement, maintenance, contrôle de qualité, et support aux utilisateurs,
  pour le projet logiciel ABINIT : structure électronique des matériaux, nanosystèmes
  et molécules d'après les premiers principes.
  Convention N° 2.4.589.09.F - duration : 01/01/2009 – 31/12/2012

(Profs J.-.C Charlier, X. Gonze, and G.-M. Rignanese)

- FRFC Project funded by the FNRS
  Imagerie et contrôle du transport de charge dans des nanodispositifs
  Convention N° 2.4.546.08 - duration : 01/01/2008 – 30/10/2011 - (Total 310.000 €)
  (Profs J.-.C Charlier, B. Hackens, and V. Bayot)

Belgium Interuniversity Attraction Pole on « Physics of interface-driven functionalities in advanced electronic materials »
PAI- IUAP P7/XX (2012-2017) - duration : 01/03/2012 – 28/02/2017 - (Total – still not defined !)
(Promoters V. Bayot, J.-.C Charlier, X. Gonze, B. Hackens, S. Melinte, L. Piraux, and G.-M. Rignanese)

- Flemish Science Foundation (FWO-Vl)

  Interplay between atomic layers and functional adsorbates

  Duration : 1/1/2012 – 31/12/2015 – Total : 480.000 Euro

  (UA : F. Peeters ; KUL : C. Van Haesendonck ; UH : P. Wagner)

- Flemish Science Foundation (FWO-Vl)

  Electronic structure of patterned graphene

  Duration : 1/10/2011 – 30/9/2014 – Total : 250.000 Euro

  Postdoc fellowship for Dr. O. Leenaerts

- Interuniversity Attraction Poles (Belgian Science Policy)

  Physics of interface-driven functionalities in advanced electronic materials

  Duration : 1/3/2012 – 28/2/2017 – Total : 500.000 Euro

CYPRUS

Country	CYPRUS
Contact (name, email)	K. MOULOPOULOS cos@ucy.ac.cy
Organisation	UNIVERSITY OF CYPRUS

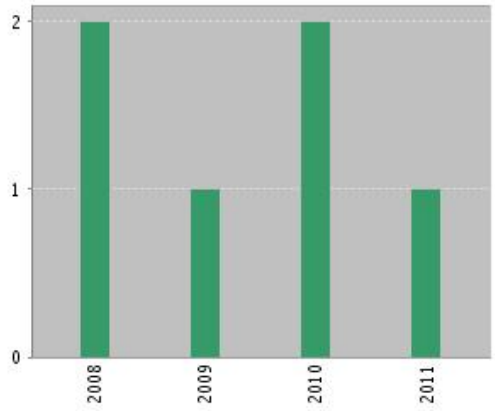
Summary of scientific activities and funding

Research on Graphene is practically non-existent in Cyprus (there have been in the past only a few theoretical papers by postdocs) although there appears to be a lot of interest (by a few experimentalists) in moving in this area. However, it has to be noted that, the tragic accident of this summer in Cyprus (an explosion that destroyed 60% of the country's electric production) combined with the economic crisis that has started hitting Cyprus (also related to the current awful status of the economy in Greece, with which Cyprus is much connected (i.e. banking system)) makes this period the hardest I have ever seen in my last 15 years in Cyprus. This is why, in spite of a declared interest in this activity, the Cyprus government, Universities and other public or private Institutes seem to currently be extremely immobile in releasing funds, especially without having a small guarantee for a profitable outcome.

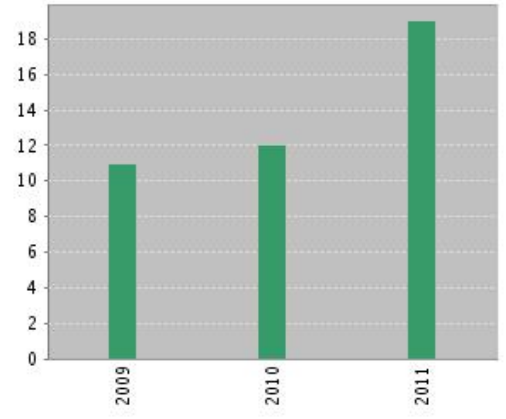
Scientific output

Publications:

Published Items in Each Year



Citations in Each Year



Patents	
Applicants	4
Inventors	1
Research institutes / Number of PIs	
University of Cyprus	1
Research funding	
Total number of PIs	1
Total number of active research groups*	2
National research funding per year for 2011 (in k€)	N/A
SMEs and Industrial R&D activity	
Research Infrastructures	
Future activities	

* *Only data submitted via web portal www.graphene-flagship.eu*

ESTONIA

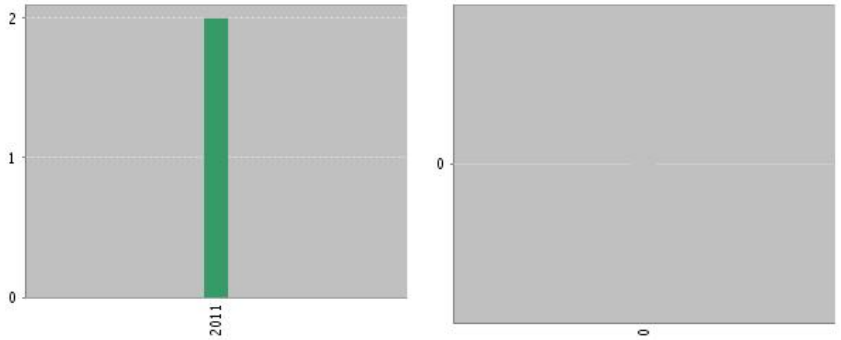
Country	Estonia
Contact (name, email)	Harry Alles, harry.alles@ut.ee
Organisation	University of Tartu

Summary of scientific activities and funding

The graphene studies in Estonia are currently concentrated to the Institute of Physics of the University of Tartu (IPUT) which participates in two international graphene projects: ENTS and RODIN. In ENTS-project, the task of Estonian materials scientists is to develop and advance methods for preparation of spin-dependent tunnel junctions and ferromagnetic materials on graphene using atomic layer depostion (ALD) method and/or combining this method with electron-beam deposition (EBE) technique. In RODIN-project, IPUT participates in the activity of annealing and characterization (mainly with Raman spectroscopy) of diamond-like-carbon (DLC) films. Also, the chemical vapor deposition (CVD) processes are being developed in Tartu in order to synthesize good-quality graphene sheets for manufacturing tunable graphene resonators with electronic read-out which is the main goal of the RODIN-project. Through these two international projects Estonian materials scientists have especially close cooperation with research institutions and industrials partners in Finland (Aalto University, Diarc Oy, Nokia Oy, Renesas Mobile), but also in Sweden (Chalmers University of Technology), United Kingdom (University of Cambridge) and other countries (The Netherlands, Germany, Switzerland). Inside Estonia, the graphene-related collaboration of IPUT scientists takes place with the physisists of National Institute of Chemical Physics and Biophysics in Tallinn, where the quality of large-area graphene sheets prepeared in IPUT by CVD method has been investigated using far infrared radiation.

In addition to international graphene projects, one national project (MTT1) purely on graphene is running in Tartu. The main goal of this project is the development of highly sensitive chemical sensors based on graphene. At the same time, in several national research projects running in IPUT, graphene is involved as a possible novel material for instance in corrosion and luminescence studies. Theoretical studies of graphene have also been started at IPUT.

The infrastructure for graphene studies in IPUT is described under *Research Infrastructures*.

Scientific output	
Publications: Timespan=2010-2011. Databases=SCI-EXPANDED, SSCI, A&HCI. **Published Items in Each Year** **Citations in Each Year**  	
Patents	
Applicants	0
Inventors	0
Research institutes / Number of PIs	
University of Tartu	2
Research funding	
Total number of PIs	2
Total number of active research groups*	1
National research funding per year for 2011 (in k€)	128

* *Only data submitted via web portal www.graphene-flagship.eu*

SMEs and Industrial R&D activity
Below is a list of names (and web pages) of 3 SMEs in Estonia which could potentially be interested in graphene R&D. With *Skeleton Technologies* we have already carried out relevant discussions. *Skeleton Technologies* (http://www.skeletontech.com/), manufacturer and developer of high energy and power density ultracapacitors *Elcogen* (http://www.elcogen.ee/), developer and provider of high quality, cost effective, scalable and sustainable solid oxide fuel cell solutions *Crystalsol* (http://www.crystalsol.at/), developer of an entirely new type of flexible photovoltaic technology In addition, we have *Estonian Nanotechnology Competence Center (ENCC)* (http://encc.ee/), a consortium of industrial and science partners formed for performing common research in the field of nanotechnology (including graphene), results of which will be basis for development of new products and/or new research of consortium partners.
Research Infrastructures
For preparation of graphene, a CVD reactor has been constructed and is now in use at IPUT. Rapid thermal annealing (RTA) equipment can be applied for modification of the properties of graphene layers. Graphene can be routinely characterized by micro-Raman spectroscopy as well as scanning probe, e.g. atomic force microscopy (AFM) and electron/ion beam microscopy tools. In addition, the research teams of IPUT have in their possession an ultrahigh-vacuum surface station with the main component – electron spectrometer – measuring energy distributions of electrons excited by an X-ray source or helium lamp. An electron gun, LEED assembly and evaporation cells have recently been added to the system. Several other methods such as reflection high energy electron diffraction (RHEED), X-ray diffraction (XRD), X-ray reflection and small angle X-ray scattering methods can be applied for characterization of graphene-based structures. In order to integrate graphene into complex solid-state structures electron beam evaporation (EBE), magnetron sputtering, pulse laser deposition (PLD) and atomic layer deposition (ALD) methods can be used for deposition of metal and dielectric layers on graphene. List of major equipment: 1. CVD reactor for preparation of graphene 2. Rapid thermal annealing equipment 3. Electron beam evaporation equipment

4. Magnetron sputtering equipment
5. ALD reactors
6. Micro-Raman spectrometer
7. Scanning probe microscopes
8. Scanning electron and focused ion beam microscope (SEM-FIB)
9. X-ray diffraction, X-ray reflection and small-angle X-ray scattering equipment
10. X-ray fluorescence spectrometer
11. Ultrahigh vacuum surface analysis station
12. Testing set-up for chemical sensors

Future activities

Future activities will include theoretical studies, development of methods for preparation of graphene, integration of graphene in multilayer structures, advancement of (non-destructive) characterization methods and different applications of graphene (sensors, components of electronic devices, coatings, etc). According to the Estonian Research Infrastructures Roadmap project *Nanomaterials – Research and Applications*, within the next few years a considerable improvement of infrastructure is expected, which includes, for instance, the purchase of analytical STEM; ca 1,7 MEUR) and the upgrade to HR analytical Scanning Electron Microscope (SEM), both improvements being very valuable for graphene-related studies.

FINLAND

Country	FINLAND
Contact (name, email)	Pertti Hakonen, pertti.hakonen@aalto.fi
Organisation	Aalto University, School of Science

Summary of scientific activities and funding

A large part of the graphene work in Finland has been theoretical. Several different methods have been employed in these studies: first principles approach, molecular dynamics, tight binding calculations, and solving of Dirac-Bogoliubov-de Gennes equation. Especially strong efforts have been put on understanding of defects and vacancies in graphene (Aalto University, Helsinki University, and Tampere University of Technology). This theoretical work has been done partially in collaboration with experimentalists abroad. In addition, magnetism of defects and additional embedded transition-metal atoms have been investigated in detail using density functional and other methods. The edges of graphene, their reconstruction and structure beyond zig-zag and armchair has also been investigated.

In collaboration between Aalto University and Nokia NRC, novel ballistic devices have been considered in order to reach new paradigms for fast electronics using graphene. In this collaboration, basic requirements (fan out, speed etc.) and prospects for mobile computing were analyzed thoroughly.

Several studies on superconductivity in graphene have been performed, including considerations for topologically protected surface superconductivity for ABC stacked graphene, which might yield a route for novel high temperature superconductors.

Gap modification both in mono- and bilayer graphene has been worked on both theoretically and experimentally. Antidot lattices have been analyzed, and the relation between the geometry and the semiconducting gap has been studied in collaboration between Aalto University and technical University of Denmark. Possible applications for spin qubits have been analyzed.

On the experimental side, several universities (Aalto University, University of Eastern Finland, Helsinki University, University of Jyväskylä) have contributed to graphene production and characterization. The experimental work has mostly been centered on the Otaniemi campus area (Aalto

University, State Research Centre VTT, Centre for Metrology and Accreditation MIKES). Graphene has been produced using exfoliation, CVD growth methods, and by decomposition of SiC. The quality of graphene has been equivalent to that obtained by other groups in the field. Samples for electrical transport have been made mostly using exfoliated samples, while CVD graphene has been used for samples of large size, like wide mechanical resonators. SiC graphene has been employed for transistors and multiterminal devices. Samples for Quantum Hall Effect have been manufactured at Aalto University for the metrology group at MIKES.

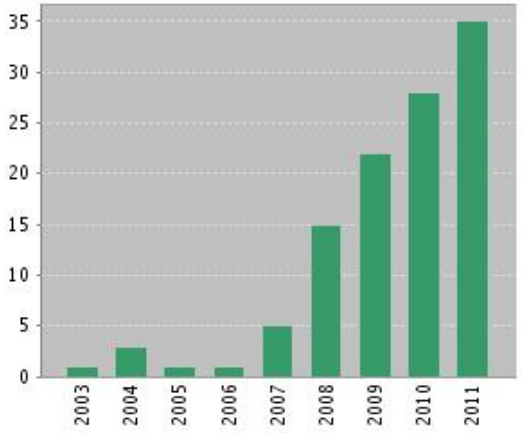
Electrical transport measurements have addressed several issues in mono- and bilayer graphene: conductivity, superlinear IV-curves, shot noise, electron-electron coupling, and electron-phonon coupling. Electrical transport has also been made on functionalized graphene, samples with adsorbed atoms, and graphene with ALD coatings of HfO_2 and Al_2O_3. The latter coating has been employed in graphene transistors, which have been measured and analyzed to facilitate the development of electrical models for circuit design purposes. Conductivity-based gas sensors have been investigated especially at VTT.

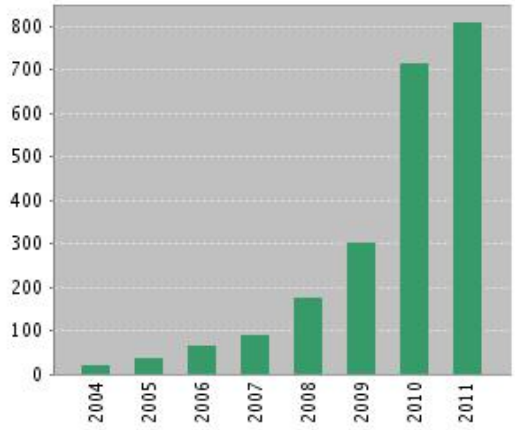
Methods for constructing complex graphene NEMS (nanoelectromechanical systems) have been developed, and the first dispersive measurements for vibration detection up to 200 MHz have been done at Aalto University. The nonlinear behavior of graphene NEMS has been investigated in collaboration between Aalto University and Cornell University. Development of tunable electrical filters based on graphene NEMS has been carried out as a collaboration among Aalto, Diarc Ltd., Renesas Mobile Finland and Nokia NRC within the European FP7 STREP-project RODIN (Suspended Graphene Nanostructures, Call: FP7-NMP-2009-SMALL-3) which includes also Chalmers University, TU Delft, ICN Barcelona, Cambridge University and Tartu University.

STM investigations on CVD graphene have been performed in a collaboration between Aalto University and Utrecht University. In this work, graphene pieces of a few nanometer in size were investigated on top of atomically flat iridium. The energy levels and wave functions have been mapped and analyzed within “particle in a box” type of approach as well as using relativistic models. Since the interaction between iridium and graphene is strong, the Dirac cones are found to be modified in these systems.

Graphene based sensors have been developed using direct electrochemistry of glucose oxidase for biosensing of glucose. In addition, interfacial engineering of graphene by proteins has been performed.

Scientific output	
Publications :	





Patents	
Applicants	5
Inventors	5
Research institutes / Number of PIs	
Aalto University	4
University of Helsinki	1
University School of Science and Technology	1
Research funding	
Total number of PIs	6
Total number of active research groups*	10
National research funding per year for 2011 (in k€)	613

* *Only data submitted via web portal www.graphene-flagship.eu*

SMEs and Industrial R&D activity
The mission of Nokia NRC (http://research.nokia.com) is to explore and develop technologies that will be available in the marketplace in five to ten years. Accordingly, NRC has been involved in the development of new paradigms for mobile technologies using graphene. Nokia NRC participates in the RODIN project, where it is one of the partners responsible for the IPR issues. Renesas Mobile Corporation (http://www.renesas.eu) develops Renesas Electronics' leading-edge mobile platforms as well as the world's foremost modem technologies, acquired from Nokia Corporation. Renesas Mobile Finland is a partner in RODIN where it is contributing to the graphene tunable filter designs through Risto Kaunisto who has a longstanding experience on these issues from earlier EU-projects. Diarc Ltd (http://www.diarc.fi) is a company that specializes in diamond like coatings (DLC). Its goal is to make DLC films to play a role in graphene growth or as a smooth substrate for graphene electronics. Diarc is participating in the RODIN project where it is developing in situ plasma enhanced CVD growth on Fe/Ni/Cu layers on silica and on ALD deposited Cu layers to target industrial scale growth of graphene combined with etching and lift off techniques to produce flakes needed for the graphene resonators. The State Research Centre of Finland (VTT, http://www.vtt.fi) has commercial interest in graphene, especially in the fields of NEMS and THz detection. The VTT graphene researchers (coordinated by Dr. Vladimir Ermelov) are involved in several collaborations within the Aalto campus area. Aivon Ltd (http://www.aivon.fi) is a high-tech company that deals with ultrasensitive measurements, especially with superconducting sensors and low-noise readout electronics. In addition to standard sensors and electronics, Aivon offers customized design, fabrication, assembly and testing. Together with its cofounder, Heikki Seppä VTT, Aivon has interest in low noise devices and detectors made using graphene. PicoSun Ltd. (http://www.picosun.com) is working to combine the excellent properties of graphene with polymers and tailored proteins to realize novel, responsive thin film structures such as graphene-polymer nanolaminates and graphene-protein biosensors. PisoSun is involved in several national/international collaborations and it offers ALD coatings and coating systems for graphene researchers worldwide.

Research Infrastructures
The Nanomicroscopy Center (http://nmc.tkk.fi/en/) is a large microscopy cluster, which houses various high resolution microscopy apparata for soft, hard and biomaterial characterization - including ultrahigh-resolution transmission electron microscope (Jeol JEM-2200FS double Cs corrector TEM), liquid helium cryo-TEM (Jeol JEM-3200FSC), scanning electron microscope (Jeol JSM-7500F SEM), scanning probe microscope (Veeco Dimension 5000 and Multimode AFM's), and UHV STM. Micronova (http://www.micronova.fi) Micronova, is a large center for the design, development and fabrication of micro- and nanosystems. Micronova is an official National Research Infrastructure since 2008. Micronova is run jointly by the VTT Technical Research Centre of Finland and Aalto University. Micronova's expert areas of applications include sensors based on microelectromechanical systems (MEMS), optical and wireless sensors, wireless communications and photonics systems, biosensors and fluidistics, nano and quantum devices, and millimeter wave and optical instruments for space applications. Micronova's modern facilities, completed in 2002, include 2600 m^2 of cleanrooms and processing lines for silicon BiCMOS, MEMS, III-V optoelectronics and thin film devices (growth of CVD graphene and annealing ovens for reduction of SiC). In addition, Micronova houses extensive laboratories for electrical and optical measurements and various types of materials characterisation. CRYOHALL of the Low Temperature Laboratory (LTL, http://ltl.aalto.fi) is one of the largest infrastructures in research at sub-mK temperatures and the scientific and technology leader among about 10 similar sites in the whole world. Since 1994, CRYOHALL has served external users as a European Large Scale Facility in FP4 - FP6. In FP6, CRYOHALL (ULTI IV) was one of the 23 single-site access-giving RIs in Europe. Presently, LTL is coordinating European Microkelvin Collaboration (2009−2013), an EU-funded FP7 network of three low temperature trans-national access-giving RIs and nine other partners (http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=ri_projects_fp7). In addition to cryostats for mK-experiments, the CRYOHALL comprises facilities for a complete graphene production line for suspended graphene samples as well as capabilities for dispersive measurements with graphene NEMS. MILLILAB (http://virtual.vtt.fi/virtual/millilab) is a microwave research facility jointly operated by VTT and Aalto University. The facility has a large collection of microwave equipment, and graphene device characterization up to 700 GHz can be performed (110 GHz on-chip and 700 GHz for waveguide experiments). Around MILLILAB there are several laboratories interested in doing circuit scale modelling of graphene devices using graphene FET models derived from experimental results. In addition to commercial services, MILLILAB facility can be accessed via collaboration

with its member laboratories.

DIARC-Technology Inc. (http://www.diarc.fi) has a large collection of CVD reactors and plasma coaters which are available on a collaborative basis.

M-GRID, the Material Science Grid (http://www.csc.fi/english/research/Computing_services/grid_environments/mgrid), is a national distributed computing environment in Finland. The idea of this national grid infrastructure is to join a number of computing clusters at different places logically into a grid, which allows users to run their applications flexibly on computing resources hosted by different institutions. The grid has been running since 2004, and it includes seven Universities at different cities of Finland: Helsinki, Espoo, Turku, Tampere, Lappeenranta, Jyväskylä, Oulu. Nearly 3000 CPU cores are presently included in the grid.

Future activities

In graphene fabrication we plan to go towards atomically controlled and modulated graphene structures, suspended samples, as well as graphene on substrates smoother than SiO_2. In the first category, the goal is to form atomically well-defined metal – graphene contacts and control the morphology of the graphene edges. These structures will first be characterized by STM, AFM, and TERS experiments. Atomic dopants and defects on graphene will also be investigated using STM. Patterning of samples will be done by cutting in an electrochemical process by applying a suitable bias voltage on the tip. Atomic control, for example by self assembly, will be employed to produce superlattices on top of graphene in order to open a semiconducting gap. Suspended samples will be done from CVD graphene and optimized for NEMS. Smooth substrates will be developed in collaboration with companies that have expertize of wafer coatings.

In suspended graphene devices, we plan to investigate nano- and microelectromechanical systems (N/MEMS) for various purposes. Especially, we are interested in the limit where quantization of phonons leads to observable consequences. Graphene devices at such limit provide new opportunities for mass detection, microwave amplification and TeraHertz detection. Moreover, graphene optomechanics at microwave frequencies forms a new paradigm that offers ample of opportunities when combined with parametric control of the resonating devices.

Functionalization of graphene surfaces will be done for sensing applications. This can be employed, for example, in conjunction with graphene NEMS. Ideally, it will be possible to follow reaction dynamics of biological reactions using functionalized graphene NEMS.

Graphene optoelectronics (detectors, photomixers, etc) will be one of the central research areas. Excitation of charge carriers by light forms the

basis of many specialized devices. For example, this principle can be employed for making THz emitters out of graphene. There are theoretical predictions on such emitters and, once the relaxation phenomena are better understood, THz emitters of graphene may be an important component filling the THz gap in the electromagnetic spectrum.

On the manufacturing side, Finnish SMEs have interest in the development of equipment for manufacturing techniques of graphene, carbon thin film materials, ALD coating of graphene, and carbon nanoparticle production in conjunction with functional applications. Furthermore, the industry is keen on the semiconductor properties of carbon and potential manufacturing techniques of carbon electronics and light weight mechanical constructions.

In addition to supporting the research above, the future theoretical graphene research will continue to develop and apply cutting-edge theoretical and computational methods to model and predict the physical properties and processing of graphene and other two-dimensional materials. We are interested in the electronic, optical, thermal, and transport properties, as well as various ways to chemically or structurally control these. In addition, the future emphasis is most likely turning towards modeling the various ways of processing graphene, including growth, doping, etching, surface reactions, ion beam modification, etc. A strong interplay between experimental and theoretical research already exists (e.g. on Otaniemi campus) and such co-operation will be further intensified in order to reach novel device concepts and new research opportunities.

FRANCE

Country	FRANCE
Contact (name, email)	Annick LOISEAU, loiseau@onera.fr
Organisation	CNRS-ONERA

Summary of scientific activities and funding

Research activities on graphene are conducted in approximately 50 research units belonging to Centre National de la Recherche Scientifique (CNRS), Universities, public research centers such as CEA (Centres d'Etudes Atomiques), ONERA (the French Aerospace Lab) and also in private companies such as Thales, Arkema. These units are networked via two national research groups (acronym is GDR): GDR GNT (title: graphene and nanotubes: science and applications, web site: http://www.graphene-nanotubes.org/) created by the CNRS in 2009, and GDR Mesoscopic Physics created in 2002 (web site: http://www.gdr-meso.phys.ens.fr/). These networks aim at fostering collaborations, scientists training, communications and dissemination via the organization of workshops, thematic schools and international conferences. Prior to 2009, this group of research was focused on nanotoubes and then extended to graphene. One should also include the national network of technology facilities (Renatech network), large instrumental facilities (synchrotron radiation facilities 'Soleil' and ESRF, high magnetic field at LCMI) (see details below).

In this landscape CEA technologies plays a special role. Based at the heart of a very strong scientific, industrial and academic environment, located both in Saclay and Grenoble, the CEA Technologies has the mission to develop and promote new technologies in the fields of Information and communications technology, energy and of diagnostics. From Nano to microsystems, or from materials to batteries, the CEA Technologies is on the cutting edge of the technological research and has a very active role in transferring knowledge towards industry (core industrial partners). This is becoming feasible thanks to technological platforms dedicated, each one, to specific industrial applications.

Research projects are funded via different programs defined either at local or national levels. At national level, the main funding sources are the programs of the ANR (Agence Nationale de la Recherche): so-called programme blanc, which is a non thematic one and devoted to basic research addressing disciplinary fields such as physics, chemistry, nanosciences…, and thematic programs focused on Nanotechnologies (P2N), materials, energetics, program Emergence etc. At the local level, funding can arise from programs at Universities (such as CPER: contrat plan –état-région, PRES and FR which are federative research programs), from foundations such as RTRA (RTRA 'Nanosciences' at Grenoble and 'Triangle de la physique' at Orsay Saclay), from regional networks such as the C'Nano network which is a national coordination of the 6 regional poles assuring the

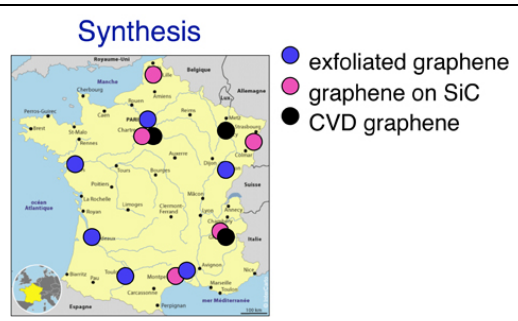
scientific animation of the activities in the nanosciences.(C'Nano Idf, GSO, Grand Est, PACA, Rh-A, NO, web site: http://www.cnano.fr/), and the 'Competitive Poles'.

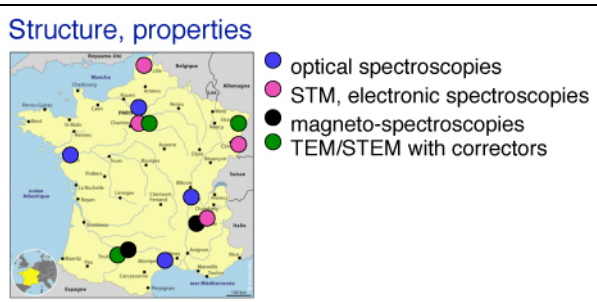
Finally, a significant fraction of fundings is issued from European commission programs of FP6 and FP7 programmes and also from ERC grants.

Research activities on graphene are focused on:

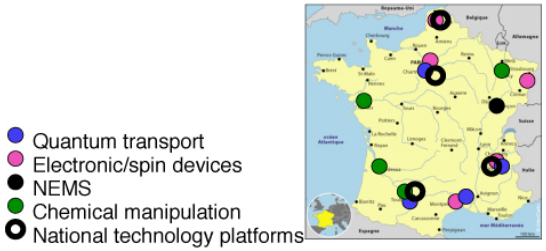
- synthesis by different techniques (exfoliation, chemical routes, CVD routes and epitaxial growth on SiC and oxide surfaces) fitting local needs and search for production techniques applications oriented, to be implemented in dedicated technology platforms
- structure characterization by TEM, near field microscopies, optical and electronic spectroscopies under magnetic field or not
- properties: transport, electronics, spintronics, supraconductivity, ultra-fast dynamics, optics, mechanical..
- chemical manipulation, functionalization, patterning, nanostructuration and patterning, bottom-up fabrication using chemical approaches
- fabrication and studies of functional devices for mesoscopic transport, spintronics, ultrafast electronics, optoelectronics, photovoltaic's, NEMS, resonators, sensing...
- ab initio calculations of electronic structure, quantum transport, spectroscopic properties, growth…
- metrology applications of graphene
- implementation of graphene-based technologies in dedicated technology platforms in order to address a large spectrum of applications such as metrology, batteries, PV, organic electronics, and health & diagnostics

Geographical distribution of these activities can be found in the table below

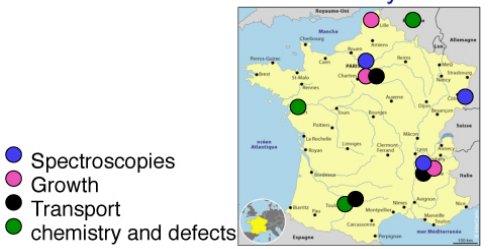




Towards devices



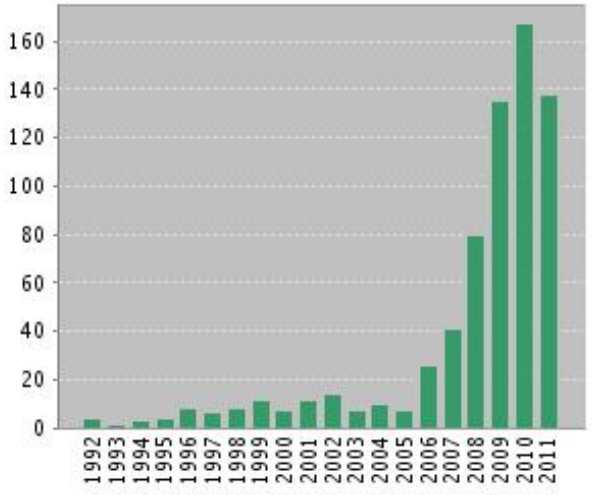
Theory



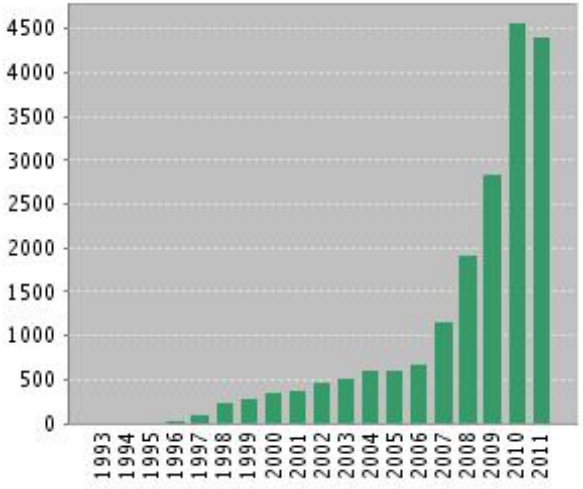
Scientific output

Publications:

Published Items in Each Year



Citations in Each Year



Patents

Applicants	14

Inventors	15
Research institutes / Number of PIs (total number of scientists)	
CNRS - Centre d'Elaboration de Matériaux et d'Etudes Structurales (CEMES) – Nanomaterials (nMat)	4 (4)
CNRS - Centre d'Elaboration de Matériaux et d'Etudes Structurales (CEMES) - NanoSciences (GNS)	1 (6)
CNRS - Laboratory of Photonics and Nanostructures (LPN)	2 (9)
CNRS – Thales - Unité Mixte de Physique CNRS/Thales (UMPhys)	N/A (3)
CNRS – Ecole Polytechnique - Laboratoire de Physique des Interfaces et des Couches Minces (LPICM)	1 (5)
CNRS - Université Aix Marseille - Centre Interdisciplinaire de Nanoscience de Marseille (CINaM)	1 (1)
CNRS – Université de Bordeaux - Centre de Recherche Paul Pascal (CRPP)	1 (7)
CNRS – Université de Bordeaux – Chimie et Biologies des Membranes et des Nanoobjets (CBMN)	1 (3)
CNRS - Université de Haute-Alsace - L'institut de Science des Matériaux de Mulhouse (IS2M)	1 (5)
CNRS – Université de Nancy - Institut Jean Lamour (IJL)	N/A (5)
CNRS – Université Joseph Fourier, Grenoble - Institut Néel	6 (28)
CNRS –Université Joseph Fourier, Grenoble - Laboratoire de Physique et Modélisation des Milieux Condensés (LPMMC)	1 (5)
CNRS – Université Joseph Fourier, Grenoble - Laboratoire National des Champs Magnétiques Intenses (LNCMI)	N/A (10)
CNRS – Université de Lille - Institut d'Electronique, de Microélectronique et de Nanotechnologie (IEMN)	3 (1)
CNRS - Université Montpellier 2 - Laboratoire Charles Coulomb (L2C)	N/A (17)
CNRS – Université de Nantes - Institute of Materials Jean Rouxel - (IMN)	1 (9)
CNRS - Université Paris Sud - Laboratoire de Physique des Solides (LPS)	3 (19)
CNRS - Université Paris Sud – Institut d'Electronique Fondamentale (IEF)	
CNRS – Université Paris Sud - Institut des Sciences Moléculaires d'Orsay (ISMO)	1 (N/A)
CNRS - Universités Pierre et Marie Curie, Paris 6 - Institut de minéralogie et de physique des milieux condensés (IMPMC)	3 (6)
CNRS - Université Denis Diderot, Paris 7 - Matériaux et Phénomènes Quantiques (MPQ)	N/A (4)

CNRS – Université de Provence - Institut Matériaux Microélectronique Nanosciences de Provence (IM2NP)	1
CNRS – Université de Strasbourg - Institut de Physique et Chimie des Matériaux de Strasbourg (IPCMS)	1 (9)
CNRS – Université de Strasbourg - Institut de Science et d'Ingénierie Supramoléculaires (ISIS)	1 (10)
CNRS – Université de Strasbourg - Laboratoire des Matériaux, Surfaces et Procédés pour la Catalyse (LMSPC)	(6)
CNRS –Université de Strasbourg - L'Institut de Biologie Moléculaire et Cellulaire (IBMC) - Carbon-based nanomaterials and delivery	1 (1)
Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	8 (20)
Ecole Normale Supérieure of Lyon	1 (3)
Ecole Normale Superieure of Paris - Laboratoire Pierre Aigrain	1 (18)
Grenoble Institute of Technology (IMEP)	1
Institut National des Sciences Appliquées de Lyon (INSA)	1
ONERA - the French Aerospace Lab	1 (8)
Laboratoire National de Métrologie et d'Essais (LNE)	N/A (2)
University Henri Poincaré-Nancy	2
University of Toulouse	1
Research funding/PI	
Total number of PIs	50 (224)
Total number of active research groups*	69
National research funding per year for 2011 (in k€)	3893
SMEs and Industrial R&D activity	
Thales RT at Palaiseau : The joint CNRS/Thales Physics lab "Unité Mixte de Physique CNRS/Thales" (UMPhys) was created in 1995 after a decade of collaboration between Thomson-CSF (Thales since 2000) and Albert Fert's research team at the Laboratoire de Physique des Solides in Orsay.	

* *Only data submitted via web portal www.graphene-flagship.eu*

UMPhys is formally associated to Univ. Paris Sud since 2000. In the framework of this collaboration, the discovery of the Giant Magnetoresistance effect in 1988 pioneered the field of spintronics and was acknowledged by the award of the 2007 Physics Nobel Prize to Albert Fert. Since then, the research in spintronics carried out at *UMPhys* led to numerous breakthroughs on experimental as well as theoretical sides, notably in the study of the spin-polarized tunneling effect, spin-transfer torque phenomena, spin-injection or magneto-Coulomb effects. Although spintronics can be considered as the historical heart of research at UMPhys, strong research activities have been developed in the last decade in the fields of high-Tc superconductors and signal processing as well as functional oxides. The team involved in the project is the "Spintronics and Functional Oxides" (UMPhys/Spintro) team. *UMPhys/Spintro* gathers 13 researchers (9 from CNRS and 4 from Universities), 4 CNRS research engineers, 9 PhD students and 6 postdoctoral fellows.

- **CEA Technologies at Saclay and Grenoble**: CEA Technologies has engaged early enough resources through different European and national funding projects to explore the potential of graphene for technological use. Like most of stakeholders, the graphene was first investigated for nanoelectronics. It happens at CEA Technologies through a European funding (FP7-ICT-GRAND), a French funding (XP-Graphene) and internal funding (Carnot graphene) projects. Since it was understood that graphene use can be extended to multiple applications, CEA Technologies has rapidly broadened the field of application toward energy and health topics to explore the potential of graphene as energy electrodes (PV, storage), HIM, sensors and flexible electronics. It has been done through some commitments in different European programs (FP7).

- **ONERA** - IdF : ONERA (Office National d'Etudes et Recherches Aérospatiales) is the French national aerospace research center. It is a public research establishment, with eight major facilities in France and about 2,000 employees, including 1,500 scientists, engineers and technicians. ONERA was originally created by the French government in 1946, and assigned six key missions: 1) direct and conduct aeronautical research, 2) support the commercialization of this research by national and European industry, 3) construct and operate the associated experimental facilities, 4) supply industry with high-level technical analyses and other services, 5) perform technical analyses for the government, and 6) train researchers and engineers. Activities on Nanoscience and nanotechnologies are conducted by a the multidisciplinary consortium organized at Onera since 1998 **as an internal federative research network**. This consortium, partner of the Labex Nanoscience, is leaded by the LEM, the joint research unit CNRS-ONERA. It addresses many aspects of modern nanosciences: synthesis, study of their electrical and optical properties, modeling of their growth. As such, it holds a full set of scientific tools and facilities for designing, synthesizing and studying matter at the nanoscale and implementing instrumental plateforms for sensing and detection applications.

Research Infrastructures
Large research infrastructures are: **- National synchrotron facility Soleil**: SOLEIL is the French national synchrotron facility, a multidisciplinary instrument and a research facility. SOLEIL thus has a double vocation: to make the highest-performing experimental facilities in the world available to its users, and to develop cutting-edge internal scientific research activity around the synchrotron beam. Both activities are organized around its 26 beamlines, each of them managed scientifically and technically by a beamline scientist, and 3 transverse programs. Several beamline scientists from 7 beamlines, which activity is clearly belonging to the nanosciences domain are partners the NanoSaclay LabEx. Their activity can be grouped in three distinct scientific teams gathered in the *SOLEIL/Nano* lab which is presented here: - Surfaces, Interfaces and NanoSystems (lines CASSIOPEE, TEMPO, ANTARES) - Physics, Chemistry, Condensed Matter(lines DEIMOS, SEXTANTS, HERMES) - Physics, Chemistry, Soft Matter (line SIRIUS) *SOLEIL/Nano* gathers 13 researchers, 2 research engineers, 3 PhD students and 4 postdoctoral fellows. - **Proximity small scale facilities networks**: This network is part of the French National coordination effort in Nanoscience and Nanotechnology (N&N) field. From the technological infrastructures point of view, the National Nanofabrication Network was created in 2009. It issues from the organization of existing facilities in only one efficient network. It is constituted by three complementary micro- and nano- technological facilities located throughout the country: the CEA-LETI, the large CNRS infrastructure (RENATECH) and the proximity facilities. The CEA-LETI is an integration centre developing research in the field of micro- and nano- technologies, especially in silicon technologies, and their devices and systems applications; priority is given to intellectual property and to development/assessment of technology from demonstrators up to prototypes for transfer towards industry. RENATECH is an academic research infrastructure network oriented towards long term and high-risk investigations, addressing advanced and prospective technologies as well as developing a flexible enabling infrastructure; new discoveries and innovations can thus rapidly transferred to industry. The proximity small scale facilities are an academic research network having processing and characterisation tools with the vocation to complete at the local regional scale, the RENATECH national infrastructure. The 9 small scale facilities represent a technological infrastructure of about 3000m² clean rooms. The generic or specific tools in these platforms are opened to the scientific community of the different laboratories at the local scale, providing both fabrication / elaboration and characterisation access. In Smartphene, 3 of them are directly implicated in the opening of this new graphene dedicated research platform and 2 more of them are concerned by the scientific developments, and will actively contribute as primary associated collaborators.

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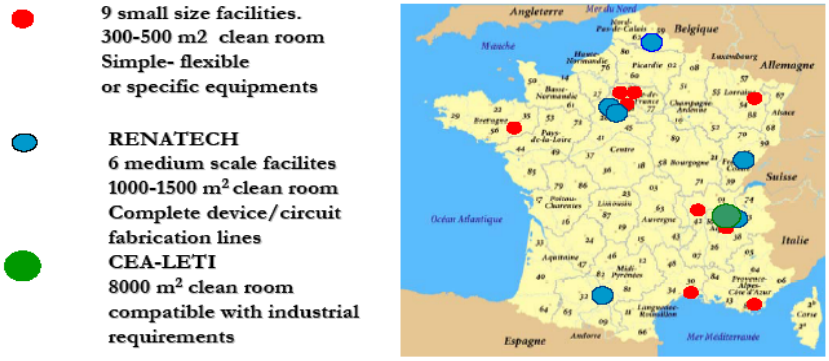
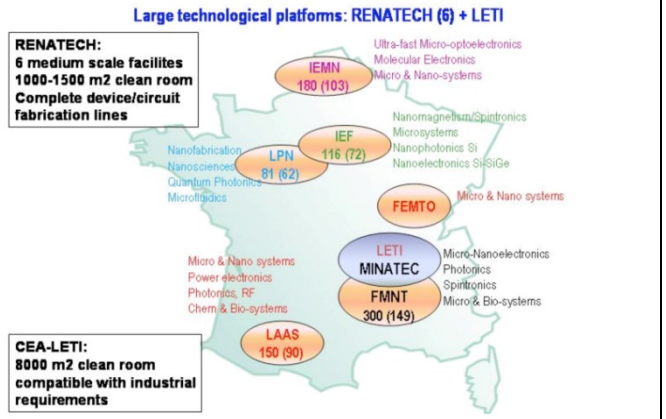


National Nanofabrication network



National C'Nano network

- **National facilities Network** (**RENATECH**): Efforts at the national level in order to coordinate and organize technological and scientific research in Nanosciences and Nanotechnology (N&N) have been a strong priority since the creation of RENATECH nanofabrication facilities in 2003. The mission of RENATECH is to reinforce the micro and nano fabrication efforts in France through dedicated facilities.

A "large technological facility" is defined as a coherent set of equipments allowing to carry out research on several technological devices or systems, of size and goals positioned between equipments dedicated to a specific process step and R&D industrial facility. The research laboratories supporting these large technological facilities are essential, leading the applied and fundamental research projects in the field of micro- nano- technologies and nano- sciences at the national and European level. The setup of the network of the large technological facilities involves a program of purchasing and renewal of the top level equipment as well as implementing resources sharing of the efforts to answer the most efficiently and at optimum cost the research needs in priority fields identified by the CNRS. The large technological facilities receive a special financial support to set up the infrastructure, equipment and top-level technological tools in order to develop the research and innovation at the best international level. The specific CNRS research objectives for the National Network of Large Technological Facilities include More than Moore, Beyond CMOS and Heterogeneous integration, also involving other topics such as photonic, optical and optoelectronic devices, as well as specific topics of the CNRS NMP work programme (Nanosciences, Nanotechnologies, Materials And New Production Technologies). **RENATECH** is thus an academic research infrastructure network oriented towards

long-term and high-risk investigations, addressing advanced and prospective technologies as well as developing a flexible enabling infrastructure. New discoveries and innovations can thus be rapidly transferred to industry. **The CEA-LETI** is an integration centre developing research in the field of micro- and nano- technologies, especially in silicon technologies, and their devices and systems applications. Priority is given to intellectual property and to development/assessment of technology, from demonstrators up to prototypes for transfer to industry.

- **National network on transmission electron microscopy (METSA):** The network has been created by the CNRS and the CNRS in 2008 in order to coordinate and organize the access and the use of advanced TEM platforms equipped with instruments of the latest generation having a scientific and technical competences internationally recognized. When created, the network was including a core of 6 platforms located in Orsay, Lyon, Grenoble, Toulouse, Rouen, Marseille. It is now extended to platforms in Strasbourg and Paris Centre. Instruments are TEM or STEM equipped with aberrations correctors, monochromators, energy filters, working at variable tensions and atomic probes. These facilities are particularly suited to the study of graphene and related nanostructures.

- **National Laboratory of high magnetic fields** (**LNCM**I): The ***Laboratoire National des Champs Magnétiques Intenses*** (LNCMI) is a French large scale facility enabling researchers to perform experiments in **the highest possible magnetic field**. Continuous fields are available at the Grenoble site (LNCMI-G) and pulsed fields at Toulouse (LNCMI-T). The LNCMI is open to European and other visitors for their high field projects, which can be submitted through the EuroMagNET web-site.

- **CEA Technologies** has the capability to implement graphene-based technologies in dedicated technological platforms (nanoelectronics & nanosystem (CEA-LETI), battery, PV, Organic electronics (CEA-LITEN), and health & diagnostics (Clinatec) that allow to address a large spectrum of application and serve as a bridge between feasibility basic research and prototyping. The potential of graphene in a real system environment could be, thus, accurately developed, investigated, tested and prototyped.

Future activities

Main national initiatives are currently emerging from the program of the governmental Research Department called ‘Investissements d’avenir’. These fundings first concern large equipments, facilities and platforms (‘Equipment of excellence corresponding to the calls Equipex1 and 2) and secondly, collaborative programs and projects defined within groups of research units gathered together in ‘laboratories of excellence’ (shortly ‘Labex). Both

projects and Laboratories are created for a period of 10 years.

Among projects already funded as an Equipex in the field of Nanotechnology and of interest for graphene research, lets us mention the projects of advanced transmission electron microscopy of the area Orsay –Saclay (TEMPOS: 13.5 Meuros)) and in Toulouse (MIMETIS: 3.5 Meuros), the project for LNCMI (LaSUP: 7 Meuros). **A national project of platform focused on the synthesis of graphene (project SMARTPHENE: 5 Meuros) and directly linked to the Flagship Graphene** has been submitted to the second call of Equipex projects. The *Smartphene* project aims at creating *a platform for the synthesis of graphene, white graphene* (hexagonal boron nitride) *graphene based nanostructures and graphene compatible materials*. The platform will focus on the recently developed chemical vapor deposition (CVD) techniques which allow the production of large scale, high-quality graphene (C) but also that of hexagonal boron nitride (BN), the III-V semiconducting variant and complement of metallic graphene and known as white graphene. The consortium, coordinated by the CNRS Institute of Physics (INP), includes 4 proximity facilities near Paris-area, Strasbourg and Grenoble, assisted by a National facility (LPN). Open to the French community via the GDR "graphene and nanotubes," "quantum mesoscopic physics" and the local networks of Nanoscience. The equipment consists of 4 specialized chemical vapor deposition reactors (CVD) in Paris Centre, Palaiseau, Strasbourg and Grenoble, and organized network. The platform includes "bottom-up" chemical synthesis. The challenge is to produce high mobility of graphene on a large scale to exploit these properties for electronic, optical and chemical sensors. The functionalization of an atom-thick membrane will be done by chemical and physical engineering of its environment: substrates, adsorbents and intercalates. The project is a global approach that includes modelling, fabrication and extensive characterization of the quality and of the new functionalities: smart substrates for electronics and optics, thin films of hBN for optics, graphene-on-insulator for photonics, hybrids multi-layer graphene (hBN, superconducting or magnetic). It will develop a body of knowledge on science and technology of graphene will be widely disseminated. It will constitute a patent portfolio, made of new processes and demonstrators made by the partners. The scaling up of the production "processes" and their transfer to industry are a key mid-term goal of the Smartphene project.

Among Laboratories of Excellence selected in the first call in 2011, let us mention the two Labex Nano-Saclay and Palm for the Region Ile de France and the Labex Lanef and Minos for the Region Rhone-Alpes, the Labex NEXT for the Region Midi-Pyrénées, all these involving graphene in their scientific skills and research programs.

GERMANY

Country	Germany
Contact (name, email)	Daniel Neumaier, neumaier@amo.de, Heinrich Kurz, kurz@amo.de
Organisation	AMO GmbH

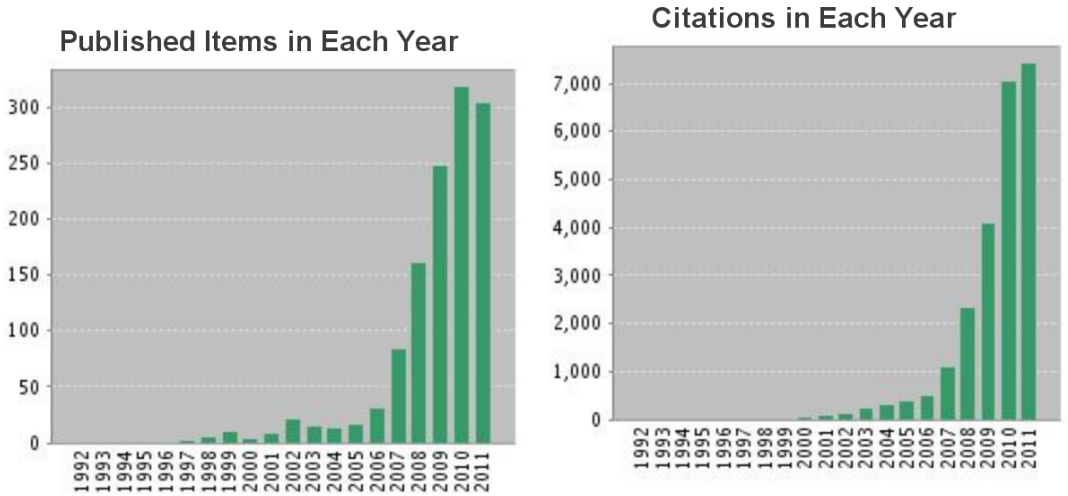
Summary of scientific activities and funding

In Germany two focused research programs on graphene were launched in 2010/2011. One is founded by the German ministry BmbF and focuses on topics mainly related to applied material science. The budget of this graphene programme is 7 Mio€ over a duration of 3 years. The second focused research program is funded by the German Science Foundation DFG and running for a total duration of 6 years. Topics addressed by this research program include fundamental science in the fields of physics, electrical engineering and material science. The budget of the graphene program is 11 Mio€ for the first 3 years. The budget for the second 3 years is not fixed so far but expected to be in the same range as for the first period. Beside these two special programs dedicated to graphene several smaller projects focussing on graphene (more than 50) are currently running.

As can be seen from the above numbers on individual projects the research is highly fragmented in Germany involving currently more than 50 individual groups. However, a detailed analysis of all research topics is hardly possible; the following topics seem to be most covered in Germany: Graphene synthesis, fundamental physics on graphene including theory, graphene based spintronics and graphene in energy applications (supercaps, batteries).

Scientific output	
Publications :	

Citation Report Topic=(graphene) AND Address=(Germany)
Timespan=All Years.
This report reflects citations to source items indexed within All Databases.



Patents	
Applicants	24
Inventors	28
Research institutes / Number of PIs	
Albert-Ludwig University of Freiburg	2
Brandenburg University of Technology	1
Christian-Albrechts University of Kiel	1
Ernst-Moritz-Arndt University of Greifswald	1
Fraunhofer Institute for Mechanics of Materials, Freiburg	1
Free University of Berlin	7

Friedrich-Alexander University of Erlangen-Nürnberg	6
Fritz-Haber Institute of Max Planck Society, Berlin	2
German Institute of Rubber Technology, Hannover	1
Gottfried Wilhelm Leibniz University of Hannover	2
Heinrich-Heine University of Düsseldorf	1
Helmholtz - Zentrum Berlin für Materialien und Energie	2
Humboldt University of Berlin	2
Johannes Gutenberg University of Mainz	1
Julius-Maximilians University of Würzburg	3
Karlsruhe Institute of Technology	3
Leibniz Institute for Solid State and Materials Research Dresden	2
Leibniz-Institut for Polymer Research of Dresden	1
Leibniz-Institut für Neue Materialien gemeinnützige Gesellschaft mit beschränkter Haftung	1
Ludwig-Maximilians University of München	1
Max-Planck-Institute for Polymer Research, Mainz	3
Max Planck Institute for Solid State Research, Stuttgart	3
Max-Planck-Institute for the Science of Light, Erlangen	1
Paul-Drude Institut für Festkörperelektronik, Berlin	N/A
Philipps University of Marburg	1
Physikalisch-Technische Bundesanstalt, Braunschweig	2
Rheinisch-Westfälische Technische Hochschule Aachen (RWTH Aachen)	5
Ruhr-University of Bochum	1
Technical University of Berlin	4
Technical University Darmstadt	1
Technical University of Dresden	1

Technical University of München	2
University of Augsburg	3
University of Bayreuth	1
University of Bielefeld	2
University of Bremen	1
University of Duisburg-Essen	3
University of Erlangen-Nürnberg	2
University of Hamburg	2
University of Köln	2
University of Konstanz	3
University of Leipzig	1
University of Osnabrück	1
University of Regensburg	5
University of Saarland	2
University of Ulm	2
Research funding	
Total number of PIs	95
Total number of active research groups*	42
National research funding per year for 2011 (in k€)	9175
SMEs and Industrial R&D activity	
In Germany several large companies are already performing active research on graphene, including BASF, Bayer and Infineon. Additionally several other companies are interested in the potential of graphene and therefore are monitoring and assessing the developments in their specific	

* *Only data submitted via web portal www.graphene-flagship.eu*

fields. The major focus of all these activities and interests can be found in the fields of composite material, energy storage, printable electronics and nano electronics.
Start-up companies in Germany dedicated to graphene are not known to me so far.
Overall the activities on Graphene in the industry sector in Germany are at the very beginning, and most of the efforts carried out at companies are still not communicated to the outside and therefore hard to monitor and assess. However I expect the situation becoming more transparent within the next years.

Research Infrastructures

Within the DFG funded graphene project several large scale investments (>50k€) were funded, including TEM (Uni Ulm), LEEM (Uni Nürnberg-Erlangen) or cryostats. Most of these equipments are not for open access.
Additionally already existing large scale equipment is used for graphene research including for instance the free-electron-laser source in Dresden Rossendorf, the high magnetic fields facilities in Dresden and several nanofabrication facilities at different locations (RWTH Aachen, FZ Jülich, Uni Regensburg, TU Munich, MPI Stuttgard…).

Future activities

The priority program on graphene funded by the DFG will be extended by 3 years to a total duration of 6 years. The budget for the extension is not fixed, but it can be expected to be in a similar range than the budget for the first period (11 M€).
From the ministry BmbF it is not clear if there will be a focused research after the WING-program on graphene finishes.

GREECE

Country	Greece
Contact (name, email)	Costas Galiotis c.galiotis@iceht.forth.gr Eleftherios Lidorikis elidorik@cc.uoi.gr
Organisation	CG : FORTH/ICE-HTCP [Research Center] EL : University of Ioannina

Summary of scientific activities and funding

The main research activities in Greece can be categorized/grouped in the following areas:

Mechanical and optomechanical properties of graphene and graphene derivatives: In particular, the characterization of graphene and other graphitic structures under all types of strain and mechanical deformations. Applications include graphene polymer nanocomposites, reinforced materials. The tools and infrastructure available in this area include optics, Raman, spectrometers, rheometer, dielectric spectrometry and polarization microscopy. Funding currently secured in this area includes €375k between 2011-2016. Main EU collaborations of Greek groups in this area include U. Cambridge, Max-Plank Inst. During the last three (3) years, Prof. Galiotis has started a fruitful collaboration with the 2010 Nobel Laureates (Novoselov/Geim) concerning the mechanical behaviour of graphene.

Growth and functionalization of graphene and graphene derivatives: Specifically, liquid phase expoliation of graphene. Electrocatalytic activity of graphene and graphene derivatives such as graphene oxide and chemically reduced graphene oxide and application of modified graphene in electrochemical sensors. The tools and infrastructure available in this area include liquid phase expholiation, solid-state pyrolisis, functionalization chemistry lab, spectroscopic, thermal and gravimetric characterization, UV-VIS-NIR, photoluminescence, ATR-IR, Electrochemistry, TGA, DSC, DLS, AFM, Micro-Raman, AFM/MFM, Micro-Raman, CCVD, Langmuir-Blodgett apparatus, SEM, Energy dispersive X-ray, spectrophotometer, 4-point electrical measurements, cyclic voltammetry. Main EU collaborations of Greek groups in this area include U. Palacky-Czech Rep., U. Groningen-Netherlands.

Graphene electronics: Activity in this area has included work on graphene as a frequency multiplier in the millimeter wave regime (~40GHz), microwave propagation, current-voltage oscillations and microwave switches. Applications targeted for graphene microwave technology, graphene-based field-effect transistors and electronics. The tools and infrastructure available in this area include device fabrication and electrical

characterization labs. Main EU collaborations of Greek groups in this area include U. Bucharest, IMT Bucharest, Romania. CNRS, France.

Theoretical-computational: activities include multiscale theoretical techniques (DFT+GCMD) for calculating the hydrogen storage capacity in graphene structures and derivatives, for application in hydrogen storage. Thermal transport (MD) on graphene pillared structures for application in graphene-based materials with tailored heat conductivity. Simulation of optical transport and photonic properties of graphene and graphene-based structures. Applications in graphene plasmonics, photovoltaics, photosensors. Main EU collaborations of Greek groups in this area include U. Cambridge.

Details about the groups working on graphene-related issues and NOT registered are demonstrated in the following:

GROWTH AND FUNCIONALIZATION

Georgakilas group (NSCR), experimental and theoretical (NOT registered)

Activities: Liquid phase expoliation of graphene

Nanothinx (Patra) (NOT registered)

Company

Activities: CNT growth

THEORETICAL - COMPUTATIONAL

Tsetseris group (NTUA), theoretical (NOT registered)

Activities: Calculations of electronic structure and properties of graphene, nanotubes, few layer graphene, and other 2D materials such as TiB2.

Giannopoulos group (Univ. Patras), theoretical (NOT registered)

Activities: Mechanical characterization and size dependent nonlinear mechanical properties of graphene nanoribbons studied by classical spring models.

In the following, the funding programmes concerning the graphene-based activity in Greece are demonstrated:

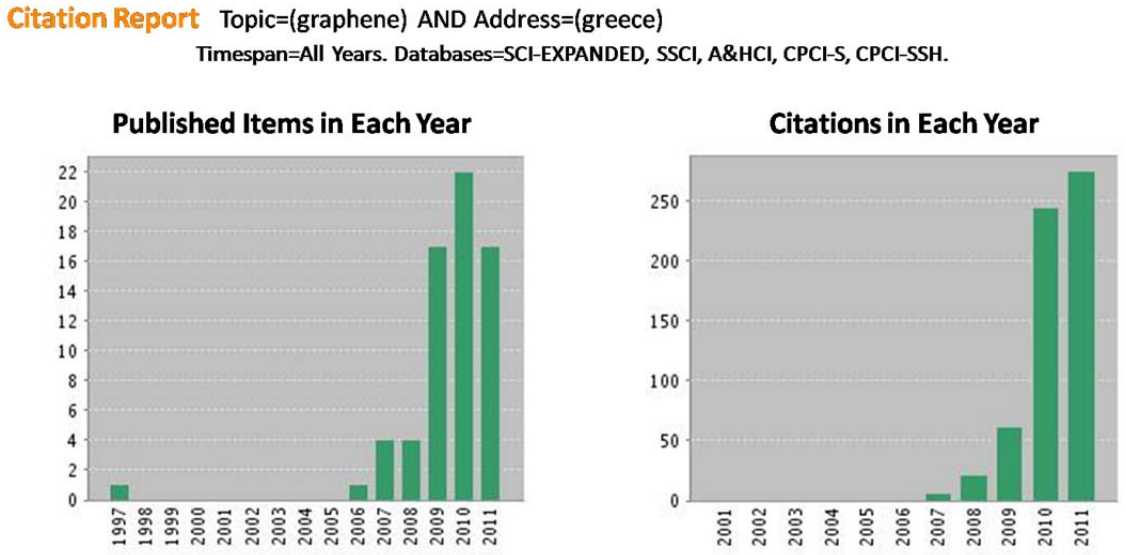
1. **Coordinator:** Floudas (Univ. of Ioannina, Greece) **Funding Source:** National **Total Funding:** 45 k€ - **Partner Funding:** 45 k€ - **Nº of Partners:** 1 **Starting Year:** 2011 - **Duration:** 3 years.
2. Call 18, Region of Epirus - Research Infrastructure of the Univ. of Ioannina NSRF 2007-2013

Coordinator: Floudas **Funding Source:** European Union **Total Funding:** 230 k€ - **Partner Funding:** 230 k€ - **Nº of Partners:** 1 **Starting Year:** 2011 - **Duration:** 5 years.

3. FGC - FORTH GRAPHENE CENTRE **Coordinator:** Costas Galiotis (FORTH/ ICE-HT, Greece) **Funding Source:** Others **Total Funding:** 100 k€ - **Partner Funding:** 40 k€ - **Nº of Partners:** 3 **Starting Year:** 2011 - **Duration:** 1 year.
4. NanoFill - Application of novel inorganic nanostructures for the development of polymer nanocomposites with improved properties **Coordinator:** S. Messaritakis (Plastika Kritis S.A., Greece) **Funding Source:** National **Total Funding:** 583 k€ - **Partner Funding:** 135 k€ - **Nº of Partners:** 4 **Starting Year:** 2011 - **Duration:** 4 years.
5. Novel nanoporous materials based on graphene: synthesis, characterization and study of properties **Coordinator:** D. Gournis (University of Ioannina, Greece) **Funding Source:** National **Total Funding:** 45 k€ - **Partner Funding:** 45 k€ - **Nº of Partners:** 1 **Starting Year:** 2010 - **Duration:** 3 years.
6. Theoretical investigation of hydrogen storage in nanoporous materials **Coordinator:** G. Froudakis (University of Crete, Greece) **Funding Source:** National **Total Funding:** 45 k€ - **Partner Funding:** 45 k€ - **Nº of Partners:** 1 **Starting Year:** 2011 - **Duration:** 3 years.

The overall funding system of graphene research in Greece in relation to the coordination of funding comes mainly from national resources, as well as, Centres of Excellence. In addition, submission of proposals through the FP7 framework is currently taking place.

Scientific output	
Publications :	



Patents	
Applicants	0
Inventors	0
Research institutes / Number of PIs	
Foundation for Research and Technology Hellas	4
National Center for Scientific Research – Institute of Material Science “Demokritos”	N/A
University of Crete	1
University of Ioannina	2
University of Patras	N/A

Research funding	
Total number of PIs	7
Total number of active research groups*	13
National research funding per year for 2011 (in k€)	189
SMEs and Industrial R&D activity	
Research Infrastructures	
Future activities	
A number of national initiatives, such as research calls (related to nanomaterials) have been launched within the last year. These include the calls THALIS, SYNERGASIA, ARISTEIA etc. A large portion of the submitted proposals are related to graphene technology. The duration of the projects will be between 2012 and 2016. In addition, through the collaboration of prominent researchers within the Foundation of Research and technology Hellas (FORTH), a Graphene Centre of Excellence is going to be established.	

* *Only data submitted via web portal www.graphene-flagship.eu*

HUNGARY

Country	Hungary
Contact (name, email)	Professor László P. BIRÓ biro@mfa.kfki.hu
Organisation	Research Institute for Technical Physics & Materials Science, Hungarian Academy of Science

Summary of scientific activities and funding

Research activity in Hungary

Experimental:

The group of Prof. Biró from the Research Institute for Technical Physics and Materials Science (MTA MFA) (http://www.nanotechnology.hu/) in collaboration with the group of Prof. Kamarás from the Research Institute for Solid State Physics and Optics (MTA SZFKI) has pioneered the nanolithography of graphene with crystallographic orientation control. Graphene nanoribbons of 2.5 nm in width, possessing a gap of 0.5 eV and perfect zig-zag edges were realized for the first time using scanning tunneling lithography (STL) and carbothermal etching (CTE), respectively.
The group of Dr. Balázsi from MTA MFA works on graphene/ceramic nanocomposites.

At the Budapest University of Technology and Economics (BME) the group of Prof. Simon works on graphene based spintronics, while the group of Prof. Mihály and Dr. Csonka on quantum transport in graphen based hybrid nanocircuits: like superconducting, ferromagnetic injection, splitting of Cooper pairs, electron entanglement or transport of quantum dots, antidot lattices.

At the University of Szeged (U-Szeged) in the groups of Dr. Kónya and Dr. Kukovecz there is work underway on the synthesis and characterization of graphene type materials, the group of Dr. Szabó works on the dispersion of graphene type materials and their functionalization and self organization.

The groups from MTA MFA, SZFKI, and the group of Dr. Kövér Institute of Nuclear Research (ATOMKI) collaborate within the framework of the Joint Korean-Hungarian Laboratory for Nanosciences (JKHLN) on the characterization and nanolithography of CVD grown graphene. The grain

structure of CVD graphene grown on Cu and the electronic properties of grain boundaries were revealed by AFM and STM.

Theory and modeling:

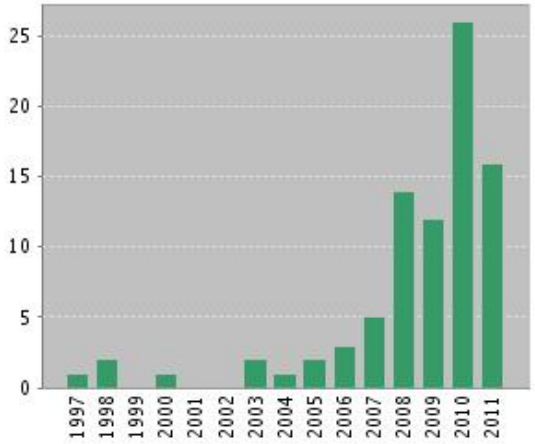
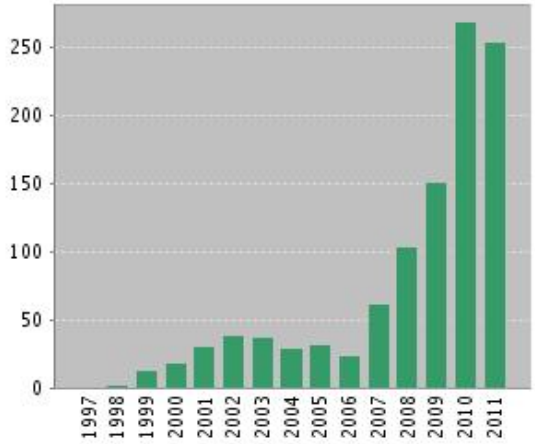
At the BME the group of Prof. Virosztek and Dr. Dóra has obtained important results in the theory of correlated physics and transport in graphene.

At the Roland Eotvos University (ELTE) the groups of Prof. Cserti and Prof. Kürti obtained important new results in the theory of spin-orbit coupling and Zitterbewegung in graphene and in first principles calculations of electron and phonon dispersions

In the group of Prof Biró in the MTA MFA atomic scale charge spreading effects on graphene are investigated by computer simulation using proprietary software. The tunneling processes from an STM tip onto a graphene sheet and the immediately subsequent charge spreading processes were investigated.

Funding programs

- Joint Korean-Hugarian Laboratory for Nanosciences (MTA MFA) (Funded by the Korean Research Council for Fundamental Science)
- Composites of graphene oxide with metal ions and biofunctional molecules (Uni Szeged) (Funded by the Hungarian Fundamental Research Fund)
- Dirac Fermions in Solids (BME) (Funded by the Hungarian Fundamental Research Fund)
- Spin dynamics and transport at the quantum edge in novel nanostructural materials (BME) (ERC grant)
- Source of Electron Entanglement in Nano Devices (BME) (ERC grant)

Scientific output	
Publications :	
Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI.	
Published Items in Each Year	**Citations in Each Year**
	
Patents	
Applicants	0
Inventors	0
Research institutes / Number of PIs	
Budapest University of Technology and Economics	3
Hungarian Academy of Sciences	4
University of Szeged	2
Research funding	
Total number of PIs	9

Total number of active research groups*	11
National research funding per year for 2011 (in k€)	145
SMEs and Industrial R&D activity	
At present no information is available on companies in Hungary involved in graphene R & D. According to most of the contacted companies this research topic has not reached yet the level at which it could have practical implication in their products. Preliminary discussions with GE Lightning Hungary indicate that in the future they might be interested in some kind of graphene related research.	
Research Infrastructures	
Two of the Hungarian research groups involved in graphene research (MTA MFA, MTA-SZFKI) are located on the KFKI campus which is the largest physics research base of the Hungarian Academy of Sciences. It has numerous large scale research facilities, from nuclear reactor, particle accelerator, electron and scanning probe microscope center, clean room facility, etc. The research infrastructures may be available to external users by case to case agreement. The two universities (BME, ELTE) involved in graphene research are the largest universities in Hungary and have multiple facilities used in physics and materials science research. The research infrastructures may be available to external users by case to case agreement. The University of Szeged has a strong chemical research background and multiple facilities may be available to external users by case to case agreement.	
Future activities	
A R & D program with national funding planned to be launched in the field of graphene research is a project application of Prof. Biró to the Hungarian Fundamental Research Fund for 2012 - 2015.	

* *Only data submitted via web portal www.graphene-flagship.eu*

IRELAND

Country	Ireland
Contact (name, email)	Prof John Boland, jboland@tcd.ie
Organisation	CRANN, Trinity College Dublin

Summary of scientific activities and funding

Funding is via national agencies Science Foundation Ireland (SFI)- (Basic Research) and Enterprise Ireland (EI)- (Applied Research), industrial research and FP7. Total funded research on Graphene: €5.64 M

This breaks down as:

SFI- €2.36 M

EI:- €370 k

EU: €2.91 M

Scientific output

Publications :

PI	papers	Citations per paper
TCD		
Ferreira		4
Coleman	17	39
Blau	3	12
Shvets	1	0
Sen	5	1
Wan CY (Mech eng TCD)	1	0
Boland	3	120

Duesberg	9	56
Gunko	3	123
Sanvito	2	8
Kristic	2	6
NUIM		
Dolan BP	1	11

Patents	
Applicants	1
Inventors	1
Research institutes/ Number of PIs	
Trinity College Dublin	3
University College Cork	2
Research funding	
Total number of PIs	5
Total number of active research groups*	5
National research funding per year for 2011 (in k€)	505

SMEs and Industrial R&D activity

Glantreo (SME) : Use of block copolymer nanolithography to generate ultra-thin grapheme ribbons. The work is used to try and open a band gap in grapheme for use in semiconductor applications.

Intel (MNC): Development of Graphene-based IC devices

HP (MNC): Graphene based sensor devices

Henkel (MNC): Development of graphene-based adhesive materials

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Research Infrastructures
UCC : Cleanrooms: distinct cleanroom spaces, 250m^2 of class 1,000 and class 10 for silicon fabrication, 750m^2 of class 10,000 and class 100 for MEMS and compound semiconductor fabrication and 40m^2 of class 1000 for e-beam lithography. CMOS, III-V & non-CMOS facilities (100 mm wafers and die-level) include: • Optical lithography (1 □m processes) • Electron beam lithography (20 nm processes) • Metal and insulator deposition • Wet and dry etching Graphene CVD furnace (negotiating joint development programme) JEOL JSM-7500F Cold-cathode field-emission SEM (including in-lens detector) Lakeshore TTP Variable Temperature (4-400 K) high vacuum / controlled atmosphere probe station (4 probe arms: DC to 40 GHz, 1 optical fibre arm) JEOL JBX-6000 FS Wafer-level Electron-beam lithography system (50 kV) JEOL 2010 TEM Picoquant MT200 Fluroescence Lifetime System (including Spectrograph and Dark-field imaging capability) Wafer-level AFM ***TCD****:* Specialised labs dedicated to photonics, nanobiology and material synthesis research. Clean room facilites provide capabilities to process materials and devices down to 500 nm using conventional lithography, in addition to the materials deposition [e-beam, sputtering, atomic layer deposition (ALD) chemical vapor deposition (CVD) and plasma enhanced CVD)] and dry and wet-etch processing. Silane capability enables implementation of nitridation process. A full suite of device characterization tools (I-V, C-V).

Advanced Microscopy Laboratory (AML) provides e-beam lithography down to 10 nm, State-of-the-art focused ion beam system capable of material modifications at 3 nm resolution SEM suite, Titan TEM with nanoscale EELS, CRANN Helium Ion Microscope,
Future activities
Development of graphene-based sensors (field-effect, electrochemical and nanoelectromechanical) is a core topic in the HEA PRTLI-5 “TYFFANI” infrastructure programme and graphene device processing will be a feature of Tyndall’s Flexifab.

ISRAEL

Country	Israel
Contact (name, email)	Oded Hod, odedhod@tau.ac.il
Organisation	Tel Aviv University

Summary of scientific activities and funding

Graphene research activity in Israel involves about 30 top rank research groups covering all the major Universities including Bar-Ilan University, Ben-Gurion University of the Negev, The Hebrew University, Technion – The Israeli Institute of Technology, Tel-Aviv University, and the Weizmann Institute of Science. Currently, the infrastructures available for graphene activity relies on state-of-the-art fabrication and characterization facilities established in the different nanocenters within Israel. These infrastructures obtained mainly via the funding of the Israeli National Nanotechnology Initiative include: micro and nano lithography facilities, dry etching capabilities, specialized spectroscopic analysis tools, visualization tools such as electron microscopy facilities (SEMs, TEM), clean rooms and specialized glove-box apparatus which allows device fabrication and characterization under controlled environmental conditions. The current infrastructures are expected to be considerably expanded with advanced facilities which will be constructed under the renewed 5-year budget of the Israeli National Nanotechnology Initiative of 112 M€. Current and future research activities involve a diversity of subjects ranging from basic science to technological applications. These include graphene synthesis and fabrication, nano-electronics applications, nano electro-mechanical applications, biological applications, energy related applications, optical applications, chemical and biological detection and sensing, and chemical catalysis, among others.

Israeli industrial activity in the field of graphene concentrates in two companies:

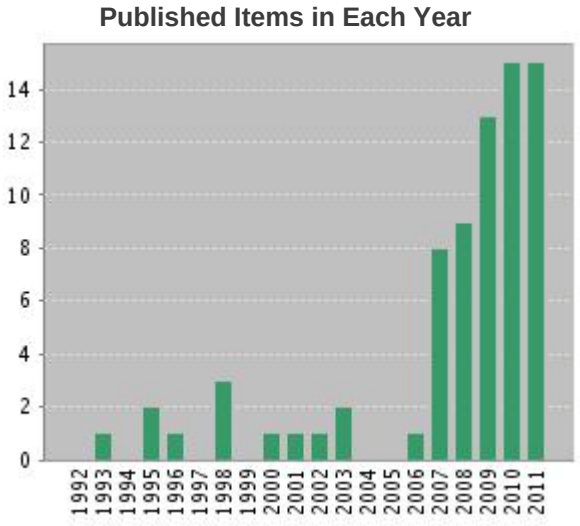
Elbit Energy is a division of Elbit Systems – an international defence electronics company – which has developed a full range of energy storage and power managements solutions that meet the demanding requirements of military and civilian markets. The division has research activities consisting of a total sum of 2M€ per year. Elbit Energy has developed an innovative aqua-based supercapacitor technology, which offers a green, cost-effective and reliable solution for high power, transportation, smart grid and renewable energy applications. The division develops state of the art, high power, high energy supercapacitors (SC) with customizable characteristics and dimensions. Elbit Energy's production line delivers a new level of efficiency and power density, cost-effective, with a unique electrode preparation process, advanced mechanical structure, resulting in highly effective capacity, extended life cycle, reliable performance and unique environmental capabilities.

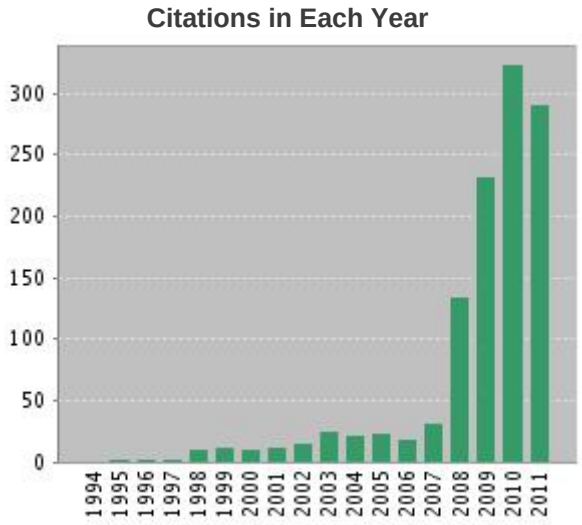
MOBIChem develops and produces a set of special pastes for electroluminescence. The set includes electroluminescent, dielectric and transparent conductive pastes and is used by their customers for manufacturing high brightness, reliable and extremely flexible electroluminescent lamps. Mobichem's activity includes: Synthesis of functional additives polymers and polymer blends, Chemical modification of carbon nanotubes, preparation of stable dispersion of nano-particles (ATO, CNT), synthesis of ion sensitive polymers, development of compositions for producing transparent and conductive coatings, preparation of stable dispersions of nano-particles, and scaling up of laboratory technological process to the pilot production both for synthesis of different compounds and the compositions.

Scientific output

Publications :

Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI.
This report reflects citations to source items indexed within Web of Science. Perform a Cited Reference Search to include citations to items not indexed within Web of Science.





Patents

Applicants	N/A
Inventors	N/A

Research institutes / Number of PIs	
Bar-Ilan University	1
Ben-Gurion University of the Negev	3
Technion – The Israeli Institute of Technology	1
Tel-Aviv University	3
The Hebrew University,	N/A
Weizmann Institute of Science	2
Research funding	
Total number of PIs	10
Total number of active research groups*	18
National research funding per year for 2011 (in k€)	176
SMEs and Industrial R&D activity	

Currently there are two companies in Israel who are interested in grapheme R&D:

Elbit

Elbit Energy

As a division of Elbit Systems – an international defence electronics company – Elbit Energy has developed a full range of energy storage and power managements solutions that meet the demanding requirements of military and civilian markets. Elbit Energy has developed an innovative aqua-based supercapacitor technology, which offers a green, cost-effective and reliable solution for high power, transportation, smart grid and renewable energy applications.

Products

Elbit Energy develops state of the art, high power, high energy supercapacitors (SC) with customizable characteristics and dimensions. Elbit Energy's production line delivers a new level of efficiency and power density, cost-effective, with a unique electrode preparation process,

* *Only data submitted via web portal www.graphene-flagship.eu*

advanced mechanical structure, resulting in highly effective capacity, extended life cycle, reliable performance and unique environmental capabilities.

Brief Summary of R&D Activities, Infrastructure and Funding

Our widespread R&D focuses on improving the current generation of Elbit's supercapacitors (SC) by application of novel, promising materials and state-of-art technologies for either the development of new electrode materials, or modification of the current activated carbon electrodes. There is a variety of scientific research activities conducted in extensive collaborations with different research groups in the academia (TAU, BIU, Technion, Hebrew University etc.) on the following topics:

a) Design of novel capacitive storage materials – modified carbons, conductive polymers, pseudo-capacitors, asymmetric capacitors etc.

b) Development of hybrid configuration of a SC and battery, combining the advantages of both devices i.e. both high power and energy density, in one solution.

c) Application of carbon nanotubes (CNTs) to achieve improved performance – better rate capability and charge utilization.

d) Development of state-of-the art technology based on novel biological materials (peptide nanotubes – PNTs) for energy storage devices.

e) Graphene as potential electrode material for energy storage application.

MOBIChem

Mobichem develops and produces a set of special pastes for electroluminescence. The set includes electroluminescent, dielectric and transparent conductive pastes and is used by their customers for manufacturing high brightness, reliable and extremely flexible electroluminescent lamps.

MOBIChem's activity includes:

- Synthesis of functional additives polymers and polymer blends (oxygen and ethylene scavengers, special photoinitiators anti foam compounds etc), developments of the special water borne, solvent borne and UV curable coatings for protection different materials (polymers, wood, stones).

- Chemical modification of carbon nanotubes.

- Preparation of stable dispersion of nano-particles (ATO, CNT).

- Synthesis of ion sensitive polymers.

- Development of compositions for producing transparent and conductive coatings on different substrates.

- Preparation of stable dispersions of nano-particles.

- Scaling up of laboratory technological process to the pilot production both for synthesis of different compounds and the compositions.

Research Infrastructures

Israeli nano-centers hold advanced state of the art fabrication and characterization facilities amenable for graphene research. Below is a list of existing equipment in several nano-centers and the two relevant companies:

Bar Ilan University's infrastructure includes the following equipment: Scanning electrom microscope, Inspect, FEI; Environmental Electron Microscope, Ouanta FEG, FEI ; XHR-SEM –High Resolution Scanning Electron Microscope, FEI, Magellan 400L; Transmission Electron Microscope, Tecnai G2, FEI is a High Contrast / Cryo TEM; JEM-1400, JEOL is a Analytical TEM; High Resolution Transmission Electron Microscope, JEM 2100, JEOL; FIB - Foused Ion Beam, FEI, Helios 600 dual beam; E-Beam Lithography, Crestec, CABL-9500C; Sputtering & Evaporation System, Bestec, GMBH; Atomic Layer Deposition, Cambridge, Fiji F200; Pulse Laser Deposition, Neocera, Pioneer 180 CCS; the Atomic Force Microscopy lab at BINA is equipped with MultiMode V, VEECO AFMs.; Atomic Force Microscope - Bruker AXS (VEECO), ICON; Rutherford backscattering spectroscopy, NEC, 5S-MR10; PPMS, Quantum Design; Superconducting Quantum Interface Device (SQUID); Magnetic Force Microscope (MFM), Autocube; Confocal Fluorescence Lifetime Imaging ,The FILM system, DCS 120, Becker & Hickl; 3D Fluorescence Recovery After Photobleaching; Absorption spectrometer and fluorimeter; Stop Flow system.

Tel-Aviv University has a well-established and a very comprehensive micro and nano fabrication facility which provides researchers access to state of the art equipment related to grapheme research. Primarily, the facilities include micro and nano lithography, including focused ion beam miller systems and a soft lithography replica-molding setup, for basic device realization (ohmic contacts, gates, etc). Dry etching capabilities support the feasibility to create suspended devices. Also at TAU are specialized micro Raman spectroscopy systems for detailed spectroscopic analysis combined with electrical characterization. Electron microscopy facilities (SEMs, TEM) offer visualization capabilities. Tel-Aviv University researchers also have access to specialized glove-box apparatus which allows device fabrication and characterization at controlled nitrogen

atmosphere to prevent damage and surface reactions in sensitive devices.

Weizmann Institute's major facilities amenable to grapheme research involve FIB and eBeam lithography and fabrication facilities, electron microscopy unit (SEMS, TEMS of different types), optical microscopy unit, a variety of NMR, EPR, AFM, STM, XPS, and just about every other methods is generally available at Weizmann, with new facilities being constantly added. The latest in this list being a new e-Beam lithography work station to be installed in the Chemistry clean rooms. Weizmann's infrastructure facilities are open to outside users.

Elbit's infrastructures are well-equipped by a variety of electrical and electrochemical measuring systems for thorough characterization of capacitors performance at different conditions (currents, temperature, voltages etc), ranging from examination of single cell capacitors in laboratory scale up to detailed evaluation of complete modules/matrixes. In addition, the wide collaboration with academia/universities enables us to use the state-of-art infrastructure in their nano-centers.

MOBIChem has the required instruments for development of laboratory scale technological processes, i.e. chemical reactors, sonicators, ball mils, stirrers, homogenizers; testing equipment i.e. spectrophotometers including fluorospectrophotometer, special testing can done by subcontractors (FTIR, ICP, Reflection in IR etc*)*

Similar equipment is available at the other institutions (Ben Gurion University, the Hebrew University, and the Technion).

Future activities

On the national level: This year, the new 5-year budget of 112 M€ for the Israeli National Nanotechnology Initiative has been approved. This budget is dedicated to the advancement of nanotechnology related research via the purchase of new fabrication and characterization infrastructure, recruitment of new researchers, and funding of new research programs. As for the existing facilities detailed above, the new infrastructure that will be purchased will be available for graphene related research.

Particular plans for graphene research in Israel include:

1. Graphene synthesis/fabrication:
   - Preparing stabilized microspheres of graphene oxide and graphene.
   - Encapsulation of drugs and other molecules in graphene microspheres

- Chemical modification of graphene.
- Fabrication of graphene nanoribbons via longitudinal cutting of multi and single wall carbon nanotubes using metal nanoparticles.
- Nanoscale resolution modification of the surface electronic and mechanical properties of graphene oxide sheets.
- Synthesis and application of novel small molecules dispersants customized for graphene and the development of ways to effectively incorporate graphene into oxide thin films.
- In-situ interfacial dynamic inverse emulsion polymerization process under sonication of aniline in the presence of graphene in organic solvents.
- Spontaneous high-concentration dispersions and liquid crystals of graphene.
- Incorporation of semiconductor and metal nanocrystals with graphene and graphene nano-ribbons.

2. Nano-electronics applications:
   - Study of electronic and spin transport properties of graphene and graphene derivatives.
   - Graphene as potential electrode materials for supercapacitor applications.
   - Magnetic properties of graphene. Measurements of the dependence of the graphene chemical potential on a magnetic field using recharging method.
3. Nano electro-mecanical applications:
   - Electromechanical devices based on boron-nitride nanoribbons and nanotubes.
4. Biological applications:
   - Antiviral properties of sulfate bounde graphen and graphene oxides.
5. Energy related applications:
   - Use of graphene in Si-based anodes for Li-batteries.
   - Study of High Tc superconductivity in doped graphane layers.
   - Inorganic 2D layered materials for hybrid solar cells applications.
   - Preparation of graphene from graphite and its dispersion in water for photovoltaic cell electrode applications.
   - Controlled deposition of metallic/hybrid metallic nanoparticles on graphene sheets for fuel cell catalysis applications.
6. Optical applications:
   - Study of nonlinear interaction between light and graphene, aiming to produce a bright,

efficient and compact source of coherent extreme ultraviolet radiation.

- Optical and photo-transport properties of hybrid systems consisting of graphene layers and semiconductor nanocrystals.
- Graphene-polymer composites: Study of the unique percolation properties of composites made of graphene flakes embedded in a polymer for optically transparent, flexible and highly conducting materials.
- Incorporation and combination of nanoparticles and graphene.

7. Detectors and sensors:
   - Study of ultra-sensitive chemical detectors based on graphene nanoribbons.
   - Self-assembled epitaxial carbon monolayer on Si for bio-sensing.
8. Chemical applications:
   - Composites containing photocatalysts CNT and/or graphene for novel photocatalysis applications.
9. Basic physics:
   - Molecular diffraction using suspended graphene layers.
   - Electronic and nuclear quantum dynamics in graphene.

ITALY

Country	Italy
Contact (name, email)	Vincenzo Palermo palermo@isof.cnr.it Vittorio Pellegrini vp@sns.it
Organisation	CNR, NEST

Summary of scientific activities and funding

Italy has been involved in 13 European projects directly related to graphene (11 running, 2 completed). This is a least number estimate, giving that some projects that also include graphene research are small-sized Marie Curie or similar projects, which have a different research topic, even if related to graphene.

Besides EU funded projects, Italian CNR is directly funding 3 research projects on graphene within the ESF EUROGRAPHENE framework, plus a variety of national FIRB and PRIN projects.

With the exception of EUROGRAPHENE, the research activity on graphene in Italy is scattered among a wide range of national (PRIN or FIRB), regional and private funding projects, and no national program dedicated to graphene is actually running.

Italian researchers are directly co-ordinating 8 of the abovementioned EU and ESF projects; the majority of the projects are focussed on nanoelectronics and microelectronics applications of graphene-based materials, on the understanding of fundamental properties of graphene and on energy application of graphene-based materials.

Besides their involvement in EU projects, there are several high-level groups working on fundamental studies of the electrical properties of graphene (theory and modelling), chemistry of graphene, research in the fields of energy storage (graphene-based supercapacitors). Photovoltaic and spintronic applications are also addressed countrywide.

Research on graphene is also part of larger research projects actually under way (such as the Energy platform-power nanosystems supported by the Italian Institute of Technology-II that targets the use of graphene and graphene structures for hydrogen storage) or under evaluation (PON projects).

Scientific output

Publications :

Publication Years	Record Count
2001	3
2002	7
2003	7
2004	7
2005	10
2006	12
2007	29
2008	47
2009	83
2010	128
2011	96
TOTAL	429

Citation Report Topic=(graphene) AND Address=(italy)

Timespan=All Years. Databases=SCI-EXPANDED, CPCI-S.

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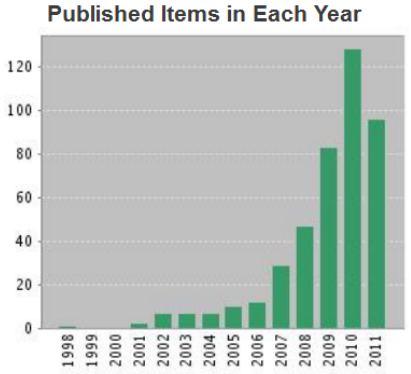
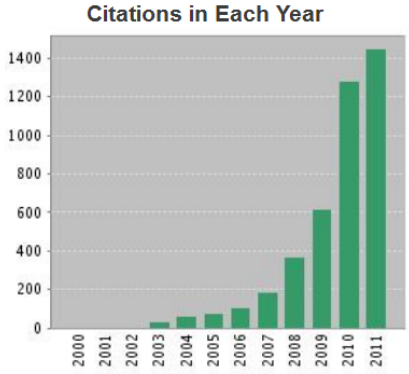




Results found: 429

Sum of the Times Cited [?] : 4191

Sum of Times Cited without self-citations [?] : 3741

Citing Articles[?] : 3304

View Citing Articles
View without self-citations

Average Citations per Item [?] : 9.77

h-index [?] : 31

Patents	
Applicants	4
Inventors	3
Research institutes / Number of PIs	
Italian Institute of Technology	1
Italian National Agency for New Technologies, Energy and Sustainable Economic Development	1
National Research Council - Institute for Organic Synthesis and Photoreactivity	1
National Research Council - Istituto per la Microelettronica e Microsistemi (IMM)	1
National Research Council - NANO Institute	2
National Research Council – Istituto di Struttura della Materia	1
National Research Council – Istituto per i Processi Chimico-Fisici	1
Politecnico di Milano	1
Politecnico di Torino	2
Scuola Normale Superiore- Laboratorio NEST	1
SiSSA school of Trieste	N/A
Università degli Studi di Modena e Reggio Emilia	1
University of Bologna	1
University of Cagliari	1
University of Catania	1
University of l'Aquila	1
University of Padova	1
University of Parma	1
University of Pavia	1
University of Perugia	2
University of Rome Tor Vergata	1

University of Salerno	1
University of Trieste	1
Research funding	
Total number of PIs	25
Total number of active research groups*	44
National research funding per year for 2011 (in k€)	522
SMEs and Industrial R&D activity	

There are different industrial sectors actually interested in graphene application and commercialization, with major companies already active in R&D research either internally or in the framework of international collaborative projects. The Research Center of FIAT is participating to three different research projects on graphene: GRENADA (study of graphene deposition and nanoscale applications), ELECTROGRAPH and AUTOSUPERCAP (graphene-based supercapacitors).

Research on graphene is also implemented in the technological district of Catania (Sicily), where STMicroelectronics has a long-lasting collaboration with researchers of CNR on the development of new materials for microelectronics (for either logic or power devices).
Besides participation to public research projects, there is industrial interest from many other, smaller industries, in the applications of graphene for the production of new composites for automotive, aerospace, consumer products, etc.

A main feature of Italy industrial landscape is the significant presence of SMEs which, while being potential beneficiaries of graphene applications, do not have proprietary R&D labs due to their reduced size. For these reasons, interest in graphene applications has been expressed by a major association of medium and large enterprises (Confindustria), which already participated to flagship-related meetings in Italy and in Brussels, and which could be potentially involved in the flagship initiative.

* *Only data submitted via web portal www.graphene-flagship.eu*

Research Infrastructures
A wide range of research labs is actually in function throughout Italy for research on graphene, potentially available for the flagship initiative. These labs include several types of small-medium facilities for graphene growth and functionalization (CVD reactors, chemical labs, etc.) for characterization (SEM, TEM, SPM, Raman) and for device production (Litography, etc.). Of these, the largest infrastructure, available even for external users, is the Synchrotron radiation beamline at Elettra, Trieste, already used by different groups for graphene-related research. Other large and medium-scale facilities which include clean rooms, ion implanters, extensive and varied microscopic and spectroscopic tools, already used for graphene production and research, are also available in the scientific poles of CNR (Bologna), CNR (Catania), NEST (Pisa), Polytechnics (Turin and Milan).
Future activities
The Italian Research Ministry is considering national initiatives to go in synergy and support the flagship initiative; the budget and funding schemes of these initiatives will be decided once the flagship selection and funding tools will be clear at European level.

LATVIA

Country	Latvia
Contact (name, email)	Donats Erts, Donats.Erts@lu.lv
Organisation	University of Latvia

Summary of scientific activities and funding

Investigation of nanostructured materials is one of 6 main supported research directions in Latvia. Although this direction is supported financially through National Research Program in Materials Science financed by Ministry of Education and Science of Latvia. Small individual grants from Council of Science of Latvia are available for investigations in the area of nanotechnologies on the base of competition with other directions. Joint research project "Development of scientific and technological potential for new nanostructured materials and its application" started in 2010.

At the moment, large infrastructure project "Development of infrastructure of National research centre for investigation of nanostructured, multifunctional materials, constructions and technologies" is launched. First clean room will be built in Latvia during realization of this project. Experimental equipment such as high resolution TEM, FIB, CVD system for fabrication of single and multilayered graphene and others will be delivered.

Graphene investigations are at the stage of starting in a few research institutes: Institute of Chemical Physics (Dr. D. Erts) and Solid State Physics Institute (Dr. Hab. I. Muzikante) of the University of Latvia, Institute of Technical Physics (Dr. Hab. M. Knite) and Institute of Polymer Materials (Dr. J. Zicans) of the Riga Technical University. Main interests of investigation are application of graphene in solar cells, sensors, electronics (University of Latvia) and fabrication, research and application of polymer/graphene composite functional materials (Riga Technical University).

Research groups at the University of Latvia have experience in work with carbon nanotubes including participation in EU FP6 and FP7 projects No. 505626 (NMP4-CT-2004-505626) DESYGN-IT *"*Design, Synthesis and Growth of Nanotubes for Industrial Technology*" and* CATHERINE *"*Carbon nAnotube Technology for High-speed nExt-geneRation nanoInterconNEcts*". Composite materials including carbon nanotubes are investigated in Riga Technical University parallel to national projects and National Research Program in materials science* in frames of FP7 project "Prevention of late stent thrombosis by an interdisciplinary global European effort" and *COST projects* MP0902

„*Composites of Inorganic Nanotubes and Polymers" (*COINAPO), COST MP0701 „Composites with novel functional and structural properties by Nanoscale materials (Nano Composite Materials - NCM)", COST FA904 „Eco-sustainable Food Packaging based on Polymer Nanomaterials"

All groups involved in graphene investigations are cooperating through National Research Program, Joint Research Project, large infrastructure project and have also joint publications.

Industry of Latvia at the moment is not involved in graphene activities but it is expected that it will start in the nearest future. It is expected that company A/S Sidrabe, which works in area of vacuum coatings, will be interested in graphene activities as electrode and active layer for solar cells. The company has close relation to the Institute of Solid State Physics of the University of Latvia in the field of coatings and properties of TCO for solar cells. Another company, which could be interested in carbon and carbon composite coatings is SIA « Nacotechnologies ».

Cooperation with groups abroad related to the graphene project are:

Institute of Chemical Physics has long term cooperation with research groups in National University Cork, CRANN Trinity College Dublin, Ireland, including 2 submitted FP7 graphene projects, Chalmers University of Technology, including running Visby project.

Institute of Solid State Physics and OLED are cooperating with Vilnius University, Kaunas University of Technology, Potsdam University Institute of Physics and Astronomy, and Gdansk University in the field of solar cells.

Institute of Polymer materials has long term cooperation with researchers from Kassel University Institute of Materials Technology. There is also submitted co-operation project (New polymeric compounds with selected nano-particles for the damping joints (NANODAMP) with Lithuanian University of Agriculture Department of Mechanical Engineering and Minghsin University of Science and Technology in the framework of the Cooperation Program between Latvia, Lithuania and Taiwan. Another submitted cooperation project (Nanostructured carbon modified polymer composites for applications in the electromagnetic fields) is together with Belarus State University, Institute for Nuclear Problems in the framework of Latvian-Belorussian Cooperation Program. In addition, we are involved in the co-operation project (together with partners from Spain and Romania (Petru Poni Institute of Macromolecular Chemistry) dealing with drug delivery, which was submitted in the framework of the last Euronanomed project call.

Scientific output

Publications :

Donats Erts Hirsh index 17, number of publications per year 3-6, citations per year app. 100

Patents	
Applicants	0
Inventors	0
Research institutes / Number of PIs*	
Institute of Chemical Physics University of Latvia	4
Institute of Solid State Physics University of Latvia	5
Institute of Technical Physics Riga Technical University	2
Institute of Polymer Materials Riga Technical University	3
Research funding*	
Total number of PIs	14
Total number of active research groups	6
National research funding per year for 2011 (in k€)	100

SMEs and Industrial R&D activity

Industry of Latvia at the moment is not involved in graphene activities but it is expected that it will start in nearest future. It is expected that company A/S Sidrabe, which works in area of vacuum coatings, will be interested in graphene activities as electrode and active layer for solar cells. The company has close relation to the Institute of Solid State Physics of the University of Latvia in the field of coatings and properties of TCO for solar cells.

Research Infrastructures

Main equipment for investigation of graphene properties in the institute of Chemical Physics are Scanning electron microscope Hitachi S4800 with e-beam lithography system Raith, Atomic force microscope Asylum research connected with inverted optical microscope, closed cycle cryostate for temperature 0.27-300 K for optical and electrical measurements. Nanomanipulation systems for investigation in situ are available for

* *Data provided by the national representative*

SEM and TEM. In 2012, CVD system for graphene synthesis will be delivered. Other equipment for electrode deposition, sample etching and cleaning and for optical and electrical measurements is available. All equipment is open for external users.

Institute of Solid State Physics of the University of Latvia has long time experience in investigations of structural, optical and electrical properties of thin inorganic and organic films. The main equipments are Optical microscope ECLIPSE L150, facility of UV region and laser spectroscopy, scanning electron microscope EVO 50 XVP, NANO indenter G200, etc., systems for deposition of thin inorganic, oxide and organic films, systems for measuring electrical, photoelectrical properties of thin films.

Main equipment for investigation of composites in the Institute of Technical Physics is universal material testing setup ZwickRoell Z2.5 with temperature chamber modified for computerized elasto-electrical and elasto-optical testing of materials, modified computerized temperature cell Linkam THMSE 600 (-170 - +300°C), originally setup for simultaneous carrying out electrical, chemical vapor absorption and dilatometric measurements.of materials for application in chemical sensors.

Institute of Polymer Materials possess equipment for manufacturing, processing and investigation of nanomaterials, including THERMO twin screw extruder, MINIJECTOR vertical injection molding machine, hydraulic presses materials; REOLOGICA cone-and-plate and plate-and-plate rotational viscometer for revealing rheological characteristics, METTLER TOLEDO thermal analysis system (differential scanning calorimeter, thermo-gravimetric property analyzer, thermomechanical analyzer and dynamic mechanical thermal analyzer) for revealing structural/relaxational features, ZWICK universal testing machine with cyclic loading option and instrumented ZWICK Charpy impact tester for characterization of mechanical behavior of nanocomposite materials, IGA equipment for measuring of gas and solvent vapor mass-transfer properties of nanocomposite materials.

Open access equipment which can be used for graphene investigations such as high resolution TEM, dual beam FIB, X ray Hall effect measurement system, etc. will be delivered in frame of project starting 2012 and will be located in different institutions. Other specific equipment is dielectric spectrometer, equipment for determination of thermal properties of materials, contact angle measuring equipment (will aid reveal surface properties of nanocarbon (int. al graphene) and its composites with polymers), Brabender mixer for obtaining small amounts of nanocomposite materials in addition to the existing twin-screw extruder (will aid obtain thermoplastics based nanocomposite materials with better dispersion of nanofiller (int. al. graphene).

The strategic plan to build up “Latvian Nanostructured Material Centre (LATNANO-C)” is proposed (2011-2020) to be realized as a world scale European (EU) Large research infrastructure for processing and study of nanostructured materials equipped with advanced technological facilities and research equipment. Methods oriented functional structure of LATNANO-C will include mutually reinforcing five fundamental parts: 1)

nanotechnologies and processing; 2) composition and structure control; 3) morphology and structuring/lithography; 4) properties and characterization; 5) application assessment.

Future activities

At the moment project “Development of infrastructure of National research centre for investigation of nanostructured, multifunctional materials, constructions and technologies” is launched. Total sum of this project is 10 865 000 EUR. During realization of this project clean room in the LATNANO centre as well as new rooms for the Institute of Chemical Physics will be built and renovated for Riga technical University.
Experimental equipment such as high resolution TEM, FIB, CVD system for fabrication of single and multilayered graphene and others for sum of 7 000 000 EUR will be delivered.
During 2012, graphene investigations will be financed by National Research Program in Material Sciences and within running projects of Council of Science of Latvia including Joint research project. New research projects oriented at graphene investigations will be applied in future project calls. Joint research project will also be applied. Expected budget may exceed 300 000 EUR per year in the future.
In the closest future it is expected to continue co-operation with existing partners and especially to develop new contacts in the framework of COST Actions in order to launch new co-operation projects in the framework of the upcoming EU FP7 calls.

THE NETHERLANDS

Country	The Netherlands
Contact (name, email)	Lieven Vandersypen l.m.k.vandersypen@tudelft.nl Guido Janssen G.C.A.M.Janssen@tudelft.nl Cees Dekker c.dekker@tudelft.nl
Organisation	Delft University of Technology

Summary of scientific activities and funding

The Netherlands is an early and enthusiastic adopter of graphene research, with highly visible contributions. Nijmegen theorist Misha Katsnelson has been a preferred partner for the Geim/Novoselov group from the early days of graphene research, is a co-author on many of their most significant papers, and is one of the most prolific theorists worldwide in the field of graphene research. Another extremely active high-level theorist is Carlo Beenakker, from Leiden University. On the experimental side, Dutch groups were among the very first (if not the first) to publish results apart from the pioneering Manchester and Columbia groups. Early experimental work includes unconventional quantum Hall effect in bilayer graphene (Nature Physics 2006, Zeitler/Katsnelson, Nijmegen, with Manchester), bipolar supercurrents in graphene (Nature 2007, Morpurgo/Vandersypen, Delft), spin injection in graphene (Nature 2007, van Wees, Groningen), and room temperature quantum Hall effect (Science 2007, Maan/Zeitler, Nijmegen, with Manchester and Columbia).

A central research direction in the Netherlands is on graphene-based electronics (made possible by a national FOM program, see below). One aspect of this work is to establish a physical understanding of the fundamental processes of Dirac electrons in graphene through a combination of theory, numerics and experiment (spectroscopy and transport). Another is the realization of electronic devices with potential for practical use and the implementation in proof-of-principle prototypes. Examples are field effect transistors relying on new switching mechanisms, spin injection and related spintronics devices, quantum dots for spin qubits with potentially very long coherence times, and graphene nanogap electrodes for molecular electronics. Integral part of this activity is research on the synthesis and functionalization of graphene, aiming at low-cost, large-scale manufacturing of graphene with high electronic quality.

In the last few years, Dutch graphene-related research has significantly expanded in scope. Examples include graphene nanopores for single-

molecule biophysics applications; graphene nanoscale structuring with electron beams, He ion beams or Ga ion beams; in-situ transport studies in a TEM to connect structure to electronic properties; graphene-substrate interactions; graphene NEMS resonators as transducers between optical and electrical signals.

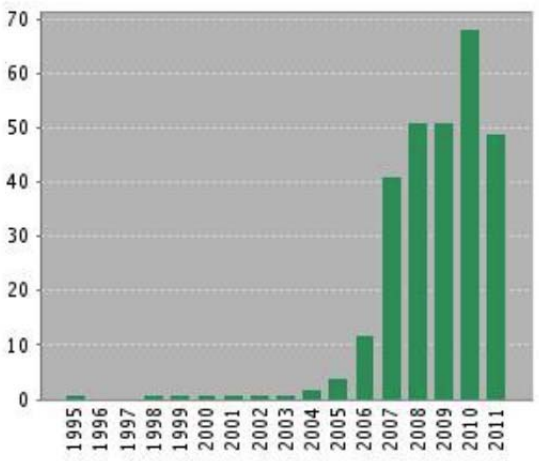
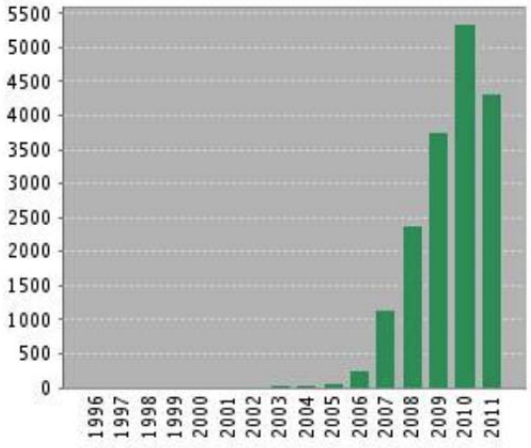
By the end of 2007, a 3.3ME program on “Graphene-based electronics” was approved by the Dutch Foundation for Fundamental Research on Matter. This illustrates the immediate and strong commitment of FOM to graphene research. The partners in this program are Vandersypen (Delft, program leader), Maan/Zeitler (Nijmegen), Katsnelson/Fasolino (Nijmegen), van Wees (Groningen), Rudolf (Groningen), Beenakker (Leiden), Aarts/Frenken (Leiden) and Janssen (Delft).

Last summer (2011), a 2.8ME program on “Graphene Technology and Applications” has been submitted to the Dutch Technology Foundation STW. In this proposal ten industrial partners participate, a.o. ASMI, NXP, Hauzer Techno Coating and Philips, who intend to collaborate with eight university groups. The aim of the proposal is to develop a scalable graphene production technology and at the same time develop applications in order to address a large part of the value chain.

The presence of large-scale infrastructure has been crucial for the work on graphene in the Netherlands. NanoLab NL has resulted in state-of-the-art nanofabrication facilities (in Delft, Twente, Groningen) that are open to all interested parties. They have been extensively used for graphene-related research. The High-field magnet lab (Nijmegen) has played an important part in uncovering the electronic properties of graphene in high magnetic fields.

A strong graphene community has been built stimulated by the FOM program. Three times a year, a “Graphene Day” is held, typically attended by about 50 scientists from the program partners groups as well as from other interested groups. The meetings rotate through different university locations and include talks on ongoing/recent work, poster sessions and lab visits. Particularly rewarding is that PhD students from different places in the Netherlands have gotten to know each other through these meetings, and a result get on the phone with each other or exchange emails to discuss fabrication issues, theoretical questions, and so forth.
In June 2012, Graphene Week, the major yearly international graphene conference, will come to the Netherlands (Delft, 4-8 June 2012).

The Dutch scientific community and its industrial partners are extremely motivated to continue their work on graphene properties and its applications, and are strongly committed to make a significant impact and contribution to the proposed flagship.

Scientific output	
Publications :	
Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH.	
Published Items in Each Year	**Citations in Each Year**
	
Patents	
Applicants	4
Inventors	5
Research institutes / Number of PIs	
Delft University of Technology	9
Eindhoven University of Technology	3
Leiden University	3
Radboud University Nijmegen	5
University of Amsterdam	1

University of Groningen	3
University of Twente	7
Utrecht University	3
Research funding	
Total number of PIs	34
Total number of active research groups*	25
National research funding per year for 2011 (in k€)	1434
SMEs and Industrial R&D activity	

In the Netherlands a number of companies have shown interest in graphene. The startup companies: Applied Nanolayers and Stratom, are interested respectively in producing graphene and integrating it into devices. Hauzer Techno coating and ASMI are equipment manufacturers, interested in producing industrial scale deposition equipment. NXP is a semiconductor company interested in integrating graphene in its IC's. Philips and Dow Chemical are interested in applying graphene in solid-state lighting and other applications for transparent conductors. Xensor integration and VSL (Dutch Metrology Institute) are interested in using graphene for Hall sensors and Quantum Hall sensors. Carl Zeiss is interested in developing He-micoscopes, essential for nano-structuring graphene.

The companies mentioned above have all joined the STW proposal "Graphene Technology and Applications" (see section on future activities), and several bring in their own money, in addition to people and infrastructure. We are very pleased by this broad consortium, since it covers a large part of the graphene value chain.

Research Infrastructures

* *Only data submitted via web portal www.graphene-flagship.eu*

NanoLab NL (http://www.nanoned.nl/nanolab-nl.html) creates, maintains and provides access to a high-level nanofabrication infrastructure in the Netherlands, which has strongly contributed to the success of Dutch graphene research. Broadly used instrumentation is made available at all the partner locations. This infrastructure is complemented by unique facilities and expertise that one would otherwise not likely find in the country.
The locations and partners in the national consortium NanoLab NL are:

- MESA+ Institute for Nanotechnology , University of Twente
- Kavli Institute of Nanoscience, TU Delft
- TNO Science & Industry
- Zernike Institute for Advanced Materials, University of Groningen.
- Philips Research (associate partner)
-

All facilities within NanoNed are open to all the NanoNed partners, as well as to external users.
In the period since the NanoLab NL initiative was launched in 2004 to the end of 2009, the partners have invested around 110 M€ in nanotechnology facilities (both from their own funds and from additional public funding, mainly NanoLab NL and BSIK NanoNed). In 2009, a 28M€ investment in nanotechnology infrastructure was made possible by NanoLab NL.

High Field Magnet Laboratory Nijmegen (HFML: http://www.ru.nl/hfml/) is one of the four magnet labs worldwide supplying DC magnetic field up to 33 T to external an internal users. Currently a 45 T hybrid magnet (operation in 2015) is under construction. The HFML is run by the Radboud University Nijmegen and FOM with support from the EU (EuroMagNET-II). With a total budget of 4 M€ per year, the HFML currently delivers 1200 magnet hours annually to 40 user experiments (1600 hours will be realised by 2013 with already secured funding). HFML is coordinator of the "European Magnetic Field Laboratory", an FP7-EU project aiming to design a blueprint for a unified infrastructure based upon the four European magnet laboratories in Nijmegen / Grenoble (DC fields) and Dresden / Toulouse (pulsed fields).
The High magnetic field played an important role in uncovering the electronic properties of graphene, and the Manchester and Columbia groups are actively performing part of their graphene research in the high field labs in Nijmegen and Tallahasse (USA).

The NIMIC consortium (Nano Imaging under Industrial Conditions, http://www.realnano.nl) aims at making a wide variety of physical, chemical and biological processes visible that take place on the scale of atoms and molecules. Powerful, new microscopes and tools are developed jointly between TU Delft, Leiden University and FEI (www.fei.com). Related to graphene, the microscopes have been used for creating graphene

nanopores and other nanosculpted structures, and probes were developed to allow in-situ transport measurements.

NeCEN (Netherlands Centre for Electron Nanoscopy, www.necen.nl) is on the roadmap for large-scale infrastructures and provides access to advanced cryo-TEMs. NeCEN is currently in the start-up phase and is expected to be operating fully in 2012. This will make it possible to study the temperature dependence of graphene properties in-situ in the TEM.

NanoLab Nijmegen has versatile, state-of-the-art equipment in Scanning Probe Methods with a broad spectrum of techniques used to investigate and to manipulate matter on an atomic scale.

Future activities

STW proposal on "Graphene Technology and Applications"

In the summer of 2011 a five-year 2.8M€ program proposal "Graphene Technology and Applications" has been submitted to the Dutch Technology Foundation STW. In this proposal ten industrial partners participate, a.o. ASMI, NXP, Hauzer Techno Coating and Philips collaborate with eight university groups. After submission of the proposal interest has been voiced by more companies, a.o. ASML and FEI. The aim of the proposal is to develop a scalable graphene production technology and at the same time develop applications in order to address a large part of the value chain.

NanoLab NL

About three years ago, NanoLab NL was included in the priorities of the Dutch National Roadmap for Large-scale Research Infrastructures. The present program ends in 2014. Efforts are made to ensure that NanoLab NL will continue to be on the Roadmap beyond 2014, so that continued investments in nanotechnology infrastructure will be made.

HFML

HFML is listed on the Dutch National Roadmap for Large-Scale Infrastructures. Additional funding via this scheme is requested at this moment. It would allow for major new investments and a considerable extension of the operation to 3000 net magnet hours in the coming five years.
Adjacent to the HFML a new free-electron laser (FLARE: http://www.ru.nl/FLARE/) has recently been realized. Together with the relaocation of the free-electron laser FELIX from Nieuwegein to Nijmegen scheduled for 2012, a unique spectroscopic facility covering a wavelength range between

4 □m and 1.5 mm will be realised soon with the possibility to couple the light to high magnetic fields up to 45 T.

FOM

Twice a year, scientists in the Netherlands can submit proposals to the open rounds of the Foundation for Fundamental Research on Matter (FOM). Budgets vary from 400k€ to 575k€. We expect that in the coming years, graphene-related proposals will continue to be successful, following the track-record of past years.

POLAND

Country	POLAND
Contact (name, email)	Wlodek Strupinski, wlodek.strupinski@itme.edu.pl
Organisation	Institute of Electronic Materials Technology, Warsaw

Summary of scientific activities and funding

Research on graphene being currently conducted in Poland comprises dynamically developing graphene mass production technology: SiC sublimation; CVD on metallic substrates; chemical synthesis - exfoliation of graphite in organic solvents and oxidation of graphite, exfoliation and reduction; ionic and covalent functionalization in order to obtain stable suspension of graphene; decoration graphene flakes by: metal, semiconductor or metal oxide nano-particles, ferromagnetics and superparamagnetic, quantum dots, etc; processing the suspension into powders, thin films or papers; physicochemical graphene modifications by wet and dry chemical methods; plasma (carbon arc and plasma jet) exfoliation of graphite in gas and liquid phase; RF plasma growth/deposition/modification of thin films; combustion and detonation synthesis in carbon-containing systems (halogenoorganic compounds, carbonates and carbon dioxide); etc. The new method of graphene growth by CVD epitaxy on SiC was developed (NanoLetters 2011, 11, 1786–1791) and production of a conductive layer consisted of graphene platelets with the use of screen printing with elaboration of a conductive polymer paste filled with graphene nanoplatelets. Research works on the graphene technology are financed through ESF EPIGRAT and „Advanced Technologies" POIG projects. The Institute of Electronic Materials Technology, where the main graphene production takes place is cooperating with numerous research groups across the world, including ESF project. Technological activities are performed alongside theoretical works. The advanced theoretical studies are realized at several universities and institutes: theoretical modeling of graphene structural properties; effects related to the pseudo-spin and valley polarization addressed by investigating the quantum transport properties; development of the efficient computational methods including the phenomenological tight-biding model, finite-element real space and momentum transfer matrix methods and density functional theory (DFT – Siesta, Abinit); theoretical researches and computer modelling of electronic structure and quantum transport via graphene nanosystems such as flakes and quantum dots to learn how universal features of quantum coherence and quantum chaos affect measurable quantities of nanosystems with Dirac electrons in comparison to standard Schroedinger electrons.

Theoretical studies are supported by several small projects: European Community's Marie Curie Research Training Network, Polish Science Foundation (FNP), Polish Ministry of Science, EU network NanoCTM, Netherlands Science Foundation NWO/FOM, FANTOMAS (FP7-PEOPLE).

Research on characterization is also being intensively developed. The structural (AFM, STM, KPFM, TEM), optical (Raman microspectroscopy, absorption) and magnetotransport methods of graphene grown on SiC and Cu are used; physical properties of metal-graphene contacts and

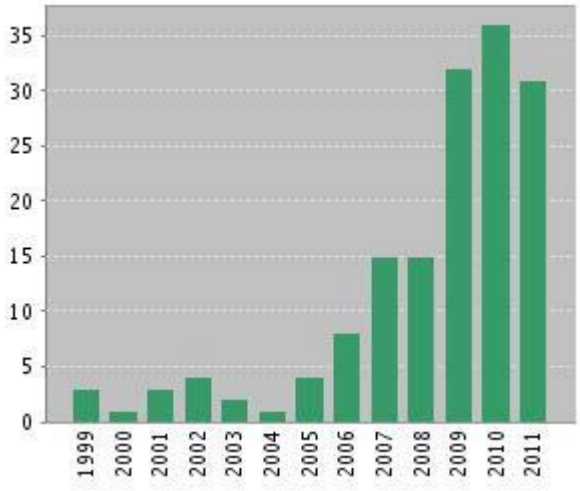
electronic structure of graphene zig-zag/armchair edges using UHV-STM/STS/CITS/AFM/KPM/ARPES/UPS/XPS/AES/LEED techniques. The strong collaboration between technology groups allows an effective improvement of the graphene layers quality.

More advanced experimental studies included magnetotransmission in THz range, as well as magnetoraman and ultrafast pump-probe experiments in magnetic field are performed in collaboration with High Magnetic Field Laboratory in Grenoble. Other characterisation studies: investigations of electrical and optical properties of graphene layers in very large spectrum of electromagnetic radiation; ellipsometric methods and x-ray spectroscopy; high resolution investigations of thermal, electrical, optical and mechanical surface properties using advanced SPM based methods, surface plasmon spectroscopy in external electric and magnetic fields; potentiometric titrations and electron spectroscopies (Csp2/Csp3 ratio); electron paramagnetic resonance (EPR) to study magnetic properties of graphene (paramagnetic centers, their nature, transition to the magnetically ordered state) and spin relaxation; investigations of mechanical and electrical properties of graphene via AFM technique; low temperature transport measurements combined with optics; studies on exchange interactions in graphene using Brillouin Light Scattering technique and Electron Paramagnetic Spectroscopy in order to determine the role of magnetic centres in graphene generated by the edge states and by various single-atom point defects. The research on graphene also includes design works for production equipment and graphene potential applications such as:

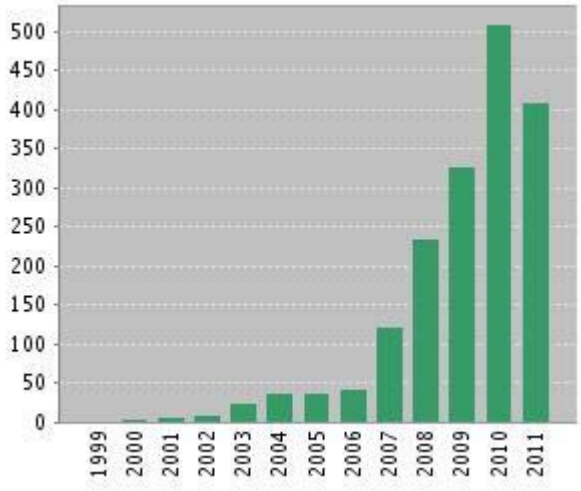
- development of the high frequency graphene transistor for application in the microwave X band with max frequency of oscillations f_1 > 15GHz, output power 0.25W, gate length 0.5μm;
- fabrication of capacitor-based and transistor-based test structures;
- photovoltaic devices based on graphene-quantum dots nanostructures;
- construction of electronic devices including its integration with CMOS technology;
- application of graphene in photovoltaics (electrode material);
- materials science (modification of mechanical and conductive properties of polymers);
- printable graphene layers for electrochemical sensors, transparent electrodes, etc;
- applications in liquid crystalline devices, organic photovoltaic devices as the acceptor material and transparent conductive anode, supercapacitors and fuel cells as the electrodes;
- applications in novel composite materials. The works are being conducted in research institutes as well as in SME and large companies.

Scientific output	
Publications :	
This report reflects citations to source items indexed within All Databases.	

Published Items in Each Year



Citations in Each Year



Patents	
Applicants	4
Inventors	1

Research institutes / Number of PIs	
Electro-technical Institute	1
Institute of Electronic Materials Technology	2
Institute of Non-Ferrous Metals	1
Polish Academy of Sciences	4
Rzeszow University of Technology	1
Silesian University of Technology	1

Technical University of Lodz	1
University of Lodz	1
University of Warsaw	2
Warsaw University of Technology	2
Research funding	
Total number of PIs	16
Total number of active research groups*	34
National research funding per year for 2011 (in k€)	483
SMEs and Industrial R&D activity	
There are about 20 companies interested in graphene R&D in Poland. One of the largest is PSE Operator SA interested in graphene application in electricity transmission sector. Another large company is Industrial Development Agency SA looking for new graphene-related materials for electronic, aerospace and automotive industry. Other companies representing different sectors: Telecolor, Thermal & Power Mechanical Eng. Energoprojekt SA, KGHM Miedz SA and others. Seco-Warwick Poland SA is already involved in works focusing on production of commercial equipment for CVD graphene growth on metallic substrates. There is also a new SME (Epi-Lab sp. z o.o.) providing graphene on SiC and Cu for research purposes.	
Research Infrastructures	
Reasearch infrastructure is divided into the following groups: **Graphene growth technology:** epi-system Aixtron –VP508 (4" size) adapted for graphene growth on SiC by sublimation and CVD method and on metallic substrates by CVD method; RF plasma enhanced reactor with innovative system for spectral diagnosis of growth zones; equipment for chemical synthesis-ultrasound disintegrator, microwave ovens, furnaces with protective and reducing atmospheres, autoclaves, high speed centrifuge, glove boxes, high energy ball mills, etc.	

* *Only data submitted via web portal www.graphene-flagship.eu*

Characterization:
HRTEM, UHV-STM, STS, CITS, AFM, KPM, ARPES, UPS, XPS, AES, LEED, Raman, Horiba Jobin-Yvon UVISEL spectroscopic ellipsometer, semi-automatic probe station equipped with extremely sensitive Keithley and Agilent peripheries and designed to measure current-voltage and capacitance-voltage characteristics within temperature range of -55° C÷+250° C, Millbrook secondary ion mass spectrometer, Hitachi scanning electron microscope, Olympus confocal microscope, Veeco profilometer, LeCroy fiber-optic spectrometer, Lambda power supplies, Raman setup combined with AFM and equipped with three laser lines (514nm, 633nm and unique 1064 nm line), He^4 cryostat for Raman setup, He^4 cryostat with magnetic field (7T) for low temperature measurement equipped with quartz window allowing to combine transport with optics, electron accelerators designed to generation and/or modification of some structural defects in graphene that influence its conductivity and percolation threshold; electron paramagnetic resonance spectrometer, X and Q band – noninvasive studies of various point defects in single and multi-layer platelets of graphene; high resolution magnetospectroscopy setup (up to 11T) allowing Raman scattering (starting from $5cm^{-1}$) with spacial resolution 1μm and selective excitation in the wide range (275-1060 nm) in wide temperature range 4-700K combined with ultrafast spectroscopy (temporal resolution down to 40fs; far infrared magnetospectroscopy (Fourier spectrometer + laser THz);

HITACHI HD2700 high resolution scanning transmission electron microscope (200 kV accelerating voltage and 0,14 nm angular resolution); HITACHI 5500 high resolution scanning electron microscope; JEM 3010 high-resolution transmission electron microscope; JEOL JEM 1200 EX II scanning-transmission electron microscope; NanoScope Multimode IIIa atomic forces microscope; Mikroskop VT AFM/STM UHV, FIB/SEM Helios NanoLab, Auger electron spectroscope with a XPS MICROLAB 350 attachment; FB-2100 ion microscope; Brillouin Light Scattering; Electron Paramagnetic Resonance; contactless sheet resistance and conductivity measurements employing dielectric resonator techniques; closed cycle helium cryostat for measurements versus temperature at temperature range 10 K – 300 K; in plans- apparatus for contactless sheet resistance and conductivity measurements in the presence of strong biasing magnetic fields;

Applications:
the clean-room (class 1000) equipped with modern facilities for optical photolithography (class 100) by Süss; PECVD and RIE processes using plasma equipment by Oxford Instruments (Plasmalabs); vacuum evaporation and sputtering of metal films; equipment for new graphene composite materials, equipment for graphene conductive layers production

Future activities

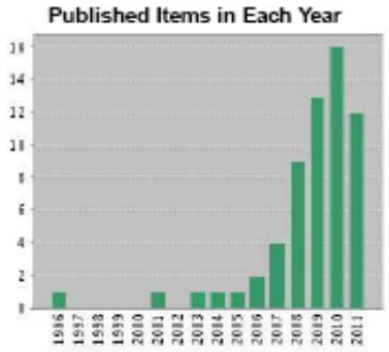
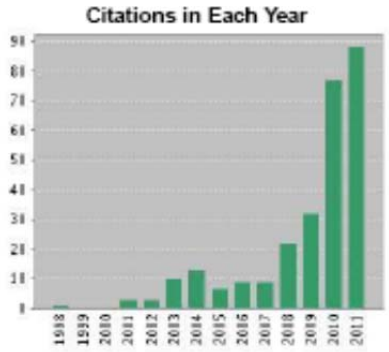
Efforts in formation of National Programme in area of graphene technology and industrial application are in progress. Final decision about this programme, its duration and budget will take place in 2012.

ROMANIA

Country	Romania
Contact (name, email)	Prof Mircea Dragoman –mircea.dragoman@imt.ro
Organisation	IMT-Bucharest http://www.imt.ro

Summary of scientific activities and funding

The main activities in graphene in Romania are done up to now in IMT-Bucahrest, Romania . Therefore, the description which follows is focalized on IMT .**IMT-Bucharest** is a unit co-ordinated by the National Authority for Scientific Research (Ministry of Education, Research, Romania).
Its main strengths lie in micro and nanotechnologies. During 2003- 2010, IMT was involved in approximately 27 European projects (FP6, FP7, and related). In some cases, IMT is co-operating with well-known international companies, for example in two ENIAC-JU projects (public-private partnership in nanoelectronics). Its Centre of Nanotechnologies is an interdisciplinary group of laboratories that uses state-ot-the-art equipment for structuring and characterisation at the nanoscale. Meanwhile, its MIMOMEMS group of laboratories – specialising in microwave devices and photonics – is a centre of excellence in RF and Opto MEMS (financed by the EC, REGPOT programme 2008-2011). Ongoing investment in equipment (e7m in 2006-2009) provides excellent support for experimental work. Through the Centre for Micro- and Nanofabrication (IMT-MINAFAB), these facilities are available to clients from industry, research and education, including a clean room area (class 1,000), as well as a “grey area” (class 100,000), where characterisation tools are installed. A new cleanroom facility (class 10,000) will become operational later this year. Apart from scientific research and technological development, IMT is active in technology transfer and innovation, as well as in education and training. Since 2005, IMT includes an autonomous Centre for Technology Transfer in Microengineering (CTT-Baneasa), and in June 2006, a Science and Technology Park for Micro- and Nanotechnologies (MINATECH-RO). The facilities provided for the companies in the park include rooms for working points, priority of access to scientific and technological services provided by IMT, as well as the possibility to install their own equipment in the technological area of IMT.

Scientific output	
Publications :  	
Patents	
Applicants	0
Inventors	0
Research institutes/ Number of PIs	
National Institute for Research and Development in Microtechnologies	1
Research funding	
Total number of PIs	1
Total number of research groups*	3
National research funding per year for 2011 (in k€)	38
SMEs and Industrial R&D activity	
The Science and Technology Park for Micro and Nanotechnologies MINATECH-RO is the first non-software ST infrastructure in Romania, focused on R&D for *micro and nanotechnologies*. The initiative of the establishment belonged to a national consortium, coordinated by the National Institute for R&D in Microtechnologies (IMT-Bucharest), and including the Polytechnic University of Bucharest (PUB) and the private	

* *Only data submitted via web portal www.graphene-flagship.eu*

company S.C. ROMES S.A.

MINATECH-RO was created and received institutional funding during 2004-2005 through the national INFRATECH Programme, administered by the Ministry of Education and Research. The financing from INFRATECH and IMT-Bucharest served for new clean room facilities, state-of-the-art equipment acquisitions and fitting out spaces for the participating companies active in the micro- and nanotechnologies field. In June 2006, the park was officially launched as a prominent Infrastructure for Technology Transfer and Innovation. IMT-Bucharest offers the main spaces, with a secondary location in PUB.

The activities of MINATECH-RO are complementary to the technology transfer projects developed by CTT-Baneasa and mostly focused on business incubation:

- Technological *transfer*: realization of prototypes, demonstrators or experimental models; small scale/pilot production after realizing the prototype
- Technological *services*, micro-physical characterization, simulation and computer aided design
- Learning/training by preparation of *courses* and stages (with practical training) in the microsystems, micro- and nanotechnologies and microengineering domains
- Assistance and consultancy activities for SMEs and small innovative enterprises: information in micro-engineering, microsystems, micro- and nanotechnologies, access to databases, documentation, etc.
- Facilitating the access of Romanian innovative SMEs to European networks and partnerships; dissemination of information (organizing conferences, workshops, editing publications, etc.)

SITEX 45 SRL

SITEX 45 SRL has been involved for over 12 years in following activities on the basis of very successfully cooperation:
- R&D and manufacturing of microelectronics components and optoelectronics devices, sensors and array sensors, transducers and microsystems as MEMS & MOEMS;
- R&D activity for new materials development and dedicated applications for micro & nanotechnologies; - Relationships with our partners as R&D institutes, universities, research offices and industrial companies by direct access to specialized processing facilities; - Design and engineering for new materials applications including nanostructured for microsystems and sensors productions;
- Design and engineering for microcontamination control and environment monitoring systems;
- Design and engineering of potential MST/sensors applications for new materials developed by a specialized partners IMNR BUCHAREST (R&D Institute for nonferrous and rare metals) for biocompatible and multifunctional thin films (materials piezoelectric, ferroelectric, core/shell structured), ceramic and polymers nanocomposite. ***[more details]***

Contact: Ghica Tei, 114, sector 2, Bucharest
Tel: 40-31-806 21 22; Fax: 40-31-811 55 63
E-mail: sitex45@rdslink.ro; sitex45@evomail.ro

COMPANIES IN IMT-MINATECH Scientific and Technological Park

EUROPEAN BUSINESS INNOVATION & RESEARCH CENTER S.A.

RTD activities and domains: AERONAUTICS and SPACE ENGINEERING MICRO- and NANO-TECHNOLOGY CLEAN and RENEWABLE ENERGY SUSTAINABLE & PRECISION AGRICULTURE

EBIC the EUROPEAN BUSINES INNOVATION & RESEARCH CENTER is a private research center (its shareholders and founders are Romanians and natural persons) and the main objectives of its activity are specific consulting and business management in innovation, scientific research and technologic research and its development within the specific programs of the European Union such as FP7, and the appropriate actions for these objectives are: assistance, support, promotion, development, dissemination, finance and project management of implementing innovation and more important the management of the EU research programs in general.
Contact: Str. Ficusului, nr.44A, sector 1, Bucuresti
Phone/ Fax: 40-21-232 37 24; 40-21-232 68 87
E-mail: ebnromania@yahoo.com

DDS DIAGNOSTIC SRL
Contact: Sos. Panduri 90-92, sector 5, Bucuresti
Phone/Fax: 021-410.40.09; Mobil: 0788 712 910
E-mail: office@ddsdiagnostic.ro, dana_stan@ddsdiagnostic.ro

TELEMEDICA SA

ROM-QUARTZ S.A
Contact: ***Calea Floreasca No. 169A***
Phone: 40-21-2331861; Fax: 40-21-2331862
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OPTOTECH SRL
Bdul Alexandru Obregia, nr.19, sector 4, Bucuresti
Phone: 40-21-683 35 69/ 0744 31 55 81;
E-mail: **optotech2006@yahoo.com**

Research Infrastructures
IMT-MINAFAB http://www.imt.ro/MINAFAB/ is an *interface* created by IMT - Bucharest in order to fully exploit its tangible and intangible assets in micro- and nanotechnologies (clean-room facility, equipments, human resources, partners and clients). The so-called “fabrication centre” is in fact *a complex technological platform* including also CAD tools, characterization equipments, a mask shop, a reliability lab. The fabrication itself, whenever necessary, is accompanied by specific testing and design, as shown in the following examples: *(i) the COVENTOR software package for modeling and simulation of microsystems provides design verification, as well as the direct input data for mask fabrication;* *(ii) the on-wafer RF testing allows immediate testing of experimental RF components;* *(iii) the nano-plotter and microarray scanner (NanoBioLab, in a clean room area) allows on-chip controlled deposition of biological molecules etc.* **Time reference**. The present clean-room environment (including class 1000 spaces) is operational since *September 2008*. Most of the equipments in this area are new. The facility was publicly launched on 9th of April 2009. Another clean room (basically devoted to CVD of thin layers and thermal processes) is expected to be completed in 2009. **Mission statement**. The micro- and nanofabrication centre from IMT-Bucharest will provide *a platform of interaction* devoted to multidisciplinary research and education-by-research, as well as to innovation and knowledge transfer to industry. As far as innovation is concerned, IMT-MINAFAB allows development of experimental models and prototypes, but also can support small scale production. Although at the moment all resources are provided by IMT, MINAFAB plans to become a platform for sharing resources with partners, as well as the central place of a national network for knowledge and technology transfer in micro- and nanotechnologies. The main equipments are found at: http://www.imt.ro/MINAFAB/description.htm
Future activities
Research **Cen**ter for **I**ntegrated **S**ystems **Na**notechnologies and **C**arbon Based **Na**nomaterials" - acronym **CENASIC** (will be launched in 2014)

using the structural founds provided by UE (value more than 600 000 Euro)

The mission of the CENASIC Center is to become a national and European excellence centre in the area of applied research in integrated micro-nanotechnologies using carbon based materials, **especially graphene**. The center will have the following main attributes: a clear-cut thematic for research, development and collaborations focused on applications highly experienced researchers and technology experts a set of state of the art R&D equipments, and laboratories designed to ensure a complete technological flux in optimal integration with the existing infrastructure, all these offering the premises for optimal collaborations with the UE research and industry and for the stimulation of demand for innovation and scientific and technological training

SPAIN

Country	Spain
Contact (name, email)	Mar Garcia Hernandez
Organisation	The Spanish National Research Council (CSIC)

Summary of scientific activities and funding

Research is active on : graphene theory and simulations ; epitaxial graphene and nanoribbons, with many people from Surface Physics steeping into the subject, electronic properties and magnetotransport, basically contributions from well-established Low Temperatures Physics ; and NEMS and Photonics. There are several chemistry groups working on graphene synthesis, graphene composites (polymeric and ceramic) as well as functionalizing graphene. Regarding devices there are groups working presently in graphene,for applications in Microelectronics, Spintronics and Wireless networks. The Spanish academic community have long term collaborations with Manchester University, Singapore Graphene Research Center, MIT, ETH, Santa Barbara , Boston University and many others.

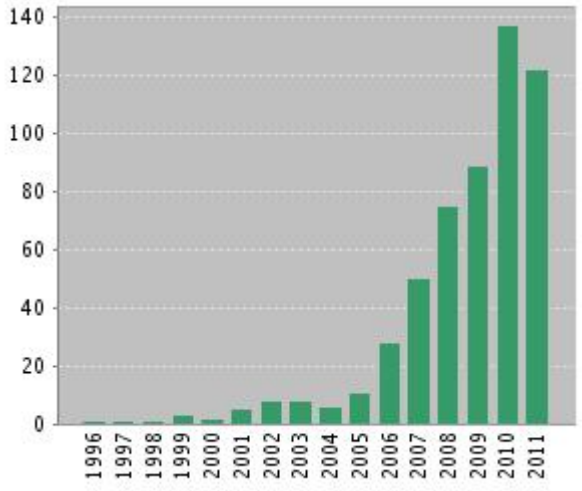
So far, there are no specific funding programs for Graphene. However, people involved in graphene research are quite successful in attracting funding from non-specific calls launched by the Ministry of Research and Innovation (MICCIN, the main funding Agency in Spain), due to the high level of excellence of the Spanish groups related to graphene. A search among MICINN data base on the projects containing the word GRAPHENE in the corresponding abstracts provides a hint of the figures about support for graphene research: in the period 2008-2010, 67 projects were funded with a total amount of 7.8 MEuro .In addition to that, several singular scientific infrastructures involved in graphene research, like Nanolithography installations, Clean rooms, Microscopy Centers open to the external users are partially supported by MICINN.
As mentioned, the major funding agency contributing to Graphene research projects is MICINN, followed by Comunidad de Madrid (3.6%), CSIC (3.47%), Basque government (1.82%) and Generalitat de Catalunya (1.097%)

Regarding industrial partners, Spain is the leading European exporter of graphene (monolayer) and graphene-like materials (5-6 monolayers). The main producers being AVANZARE (graphene and polymeric composites), GRANPH (Graphene), GRAPHENEA (Graphene). In particular, AVANZARE expects a weekly production of 300 Kg by next year.

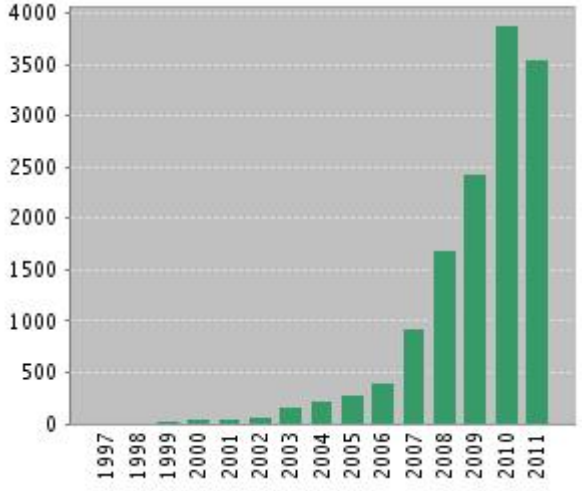
Scientific output

Publications :

Published Items in Each Year



Citations in Each Year



547 Papers,

13769 Cites (total)

25.17 Average Citation

H= 53

47% of the publications have 1 author belonging to CSIC, which leads the Spanish research on Graphene.

Patents	
Applicants	0
Inventors	2
Research institutes / Number of PIs	
Centre Català del Plàstic (CCP)	1
Centre for Electrochemical Technologies in San Sebastian CIDETEC-IK4	1

CSIC - Instituto de Ciencia y Tecnologia de Polimeros (ICTP)	2
CSIC - Instituto Nacional del Carbón	2
CSIC - Cell-Biomaterial Recognition (CIB)	1
CSIC - Centre d'Investigació en Nanociència i Nanotecnologia (CIN2)	1
CSIC - Centre Nacional de Microelectronica (CNM)	1
CSIC - Consejo Superior de Investigaciones Científicas	1
CSIC - Institute of Ceramics and Glass	1
CSIC - Instituto de Ciencia de Materiales de Madrid (ICMM)	4
CSIC - Instituto de Óptica	1
Institute of Nanoscience of Aragon	1
Instituto de Carboquímica	1
Madrid Institute for Advanced Studies of Materials (IMDEA)	1
Materials Science Institute of the University of Aragon	1
Materials Science Institute of the University of Valencia	1
Rey Juan Carlos University	1
Universidad Autònoma de Barcelona	1
Universidad Autònoma de Madrid	5
Universidad Complutense de Madrid	4
Universidad Politécnica de Madrid	1
Universidad Politécnica de Valencia	2
University Carlos III of Madrid	1
University of Alicante	1
University of Cadiz	1
University of Castilla-La Mancha	1
University of Extremadura	1

University of Granada	2
University of Salamanca	3
University of Santiago de Compostela	1
University of the Basque Country	3
University of Valladolid	1
University of Vigo	1

Research funding	
Total number of PIs	51
Total number of active research groups*	100
National research funding per year for 2011 (in k€)	666

SMEs and Industrial R&D activity

AVANZARE major exporter of grapheme in Europe. 300 Kg/week of graphene (5-6 layers),. Mainly interested in electric conducting polymer composites, heat dissipation processes (high thermal conductivity polymer composites) and high temperature applications

GRANPH belong to Antolin Group (a Spanish multinational company) They are graphene producers from carbon-nanofibers with a steadily increasing productions.

GRAPHENEA is a graphene producer (using CVD techniques) providing samples to very many labs worldwide.

Other industries that have already contacted the coordinators of GRAPHeNE (The Spanish movilizing action for graphene) and are interested in including graphene in their R&D agendas, Among them are:

- REPSOL (Grapehen photonics, plasmonics and photovoltaics, Composites and Grapehne chemistry)
-TECNICAS REUNIDAS SA (graphene production & composites with tailored mechanical properties,graphene chemistry)
-FIDAC (graphene production & composites with tailored mechanical properties, graphene chemistry)
-TECNALIA (Graphene production and mechanical properties).

* *Only data submitted via web portal www.graphene-flagship.eu*

-GEOLEN INGENIERIA SL -INDRA (graphene production & composites with tailored mechanical properties, graphene chemistry, Electronics, photonics and plasmonics) -CUADROS ELECTRICOS NANZARENOS SL (Graphene production, electronics and mechanics) - ACCIONA (Graphene electronics, composites and mechanics) -FERROATLANTICA graphene production & composites with tailored mechanical properties, graphene chemistry, Electronics, photonics and plasmonics) -SDGTECIN (Graphene production, composites and graqphene chemistry -TINDAYA RENOVABLES (Graphene production, Graphene electronics, plasmonics and photovoltaics) -FERTIBERIA SA (Graphene production & composites with tailored mechanical properties, graphene chemistry, Electronics, photonics,and plasmonics, photovoltaics) -TECNOVE SECURITY (Grapehne production, mechanics and composites) -TELEVES SA 8 graphene electronics) - IMPLASER99,SLL - Fundacion INNOVARCILLA (Grapehne production, mechanics and composites) -NANOCONECTA (Graphene production, composites and chemistry) - MMR GROUP (Graphene production). -LEARIKER (Graphene composites) -TOLSA SA (Graphene composites)
Research Infrastructures
Clean Room Instituto Nacional de Microelectronica/CSIC (Nanolithography and Microscopy Barcelona) Open to external users Instituto de Sistemas optoelectrónicos y microtecnología/UPM (Nanolithography and microfabrication, Madrid) Open to external users. Centro Nacional de Microscopia/ UCM (Madrid)(A cluster of Electron microscopies, Madrid), Open to external users. Instituto Nanotecnologia de Aragon (Nanolithography and HREM, Zaragoza).Open to external users. Instituto Catalan de Nanotecnologia/CIN2/CSIC (Clean room, Nanolithography and Microfabrication, Barcelona) IMDEA Nanoscience and Nanotecnology (Clean room, Nanolithography and microfabrication, Madrid).

Barcelona Supercomputing Certer (Computing, Barcelona).Open to external users Centro de Supercomputación de Galicia- Finis Terrae (Computing, La Coruña) Open to external users Centro de Microanálisis de Matreriales, UAM (Electrostatic Acelerator –Tandem type 5 MW, Madrid) Open to external users ICFO/Generalitat Catalunya (Microfabrication and Testingio ofoptoelectronic and NEMS devices) Instituto Iberico de Nanotecnología (Nanolithography, Microfabrication and Device testing) (Braga, Portugal) Open to external users. NanoGUNE (Nanolithography, Microfabrication and Device testing) Donosti.
Future activities
Being negociated.

SWITZERLAND

Country	Switzerland
Contact (name, email)	Alberto Morpurgo Alberto.Morpurgo@unige.ch, Klaus Ensslin ensslin@phys.ethz.ch, Christian Schönenberger Christian.Schoenenberger@unibas.ch,
Organisation	University of Geneva, ETH Zurich, University of Basel

Summary of scientific activities and funding

A number of groups in Switzerland have had significant input on the field of graphene. This includes the characterization of graphene by Raman and optical spectroscopy as well as the design and realization of graphene quantum structures.

Strategic contribution to the graphene flagship

Material development: most of the graphene experiments are still done on exfoliated graphene. In the next 5 years it will be necessary to produce high-quality graphene on large scales and in particular to fabricate nano-devices with controlled edges. This will be achieved by a combination of top-down technology using lithography and chemical etching as well as bottom-up approaches based on synthetic chemistry and catalytic reactions. Basic reaction kinetics and layer-by-layer growth will be investigated by dedicated surface science experiments in ultra-high vacuum.

Layered materials: Other layered and single-layer materials such as MoS2 and WSe2 will be realized by exfoliation and investigated by electron microscopy and transport experiments. BN will be used as a substrate for high-mobility devices and also as a gate insulator or separator between neighboring graphene layers. This entire area will be exploited in order to advance the advantageous properties of graphene to other systems and explore two-dimensional crystals in view of fundamental science questions as well as applications.

Sensors: Graphene lends itself as a strain sensor and potentially also as a mass sensor with chemical selectivity. With improved edge control one may envision sensor application which may combine physical and chemical sensing functions.

Quantum devices: Spin coherence times in graphene are expected to be long in view of the weakness of hyperfine coupling and spin-orbit interactions. These theoretical predictions have not been experimentally verified yet and experiments will be devised to explore these frontiers. Spintronics experiments in general as well as the exploitation of graphene-based spin qubits will be investigated.

TEM membranes: graphene films can replace amorphous carbon membranes, yielding superior resolution in the tomographic imaging of

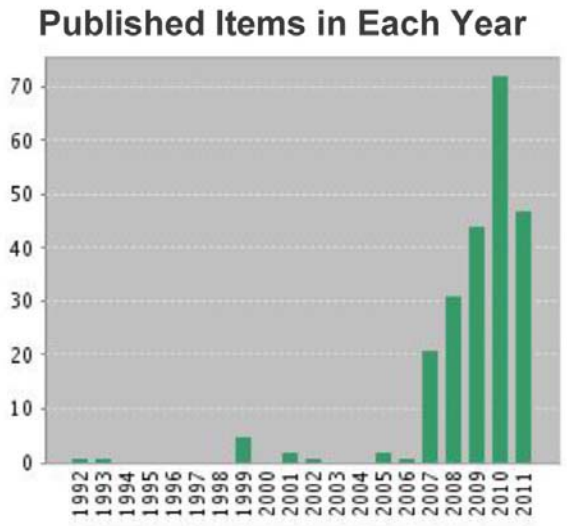
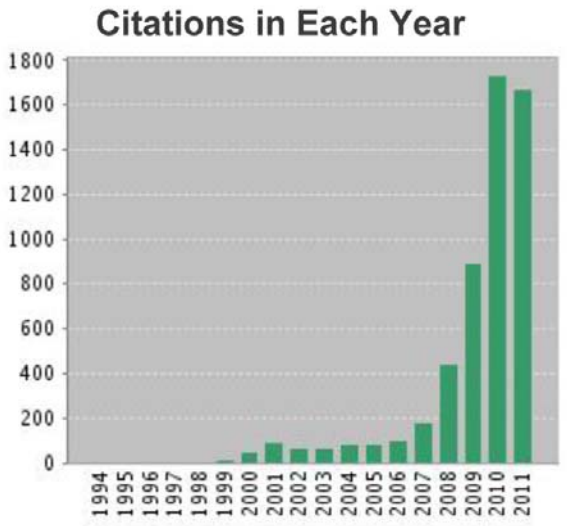
biological samples, potentially allowing to image biomoelcules unstained.

Optoelectronic devices: The unique gapless electron dispersion, ultrafast response, combined with the high mobility has sparked the interest of Graphene for photonic devices: optical sources, detectors, saturable absorbers, plasmonic devices have already been proposed with applications in the whole infrared to terahertz part of the electromagnetic spectrum.

Swiss participants:

Klaus Ensslin	ETH Zurich	Contact person
Christian Schönenberger	Uni Basel	Contact person
Alberto Morpurgo	Uni Geneva	
Daniel Loss	Uni Basel	
Dominick Zumbühl	Uni Basel	
Christofer Hierold	ETH Zurich	
Laszlo Forro	EPF Lausanne	
Andras Kis	EPF Lausanne	
Dirk van der Marel	Uni Geneva	
Jürg Osterwalder	Uni Zurich	
Harald Brune	EPF Lausanne	
Ralph Spolenak	ETH Zurich	
Jerome Faist	ETH Zurich	
Roman Fasel	EMPA	

There is no dedicated funding for graphene in Switzerland. Several groups participate in EU funding and others do graphene research using their standard grants from the Swiss National Science Foundation. Two National Centers of Competence in Research (budget ca. 4 Mio CHF per year) called MANEP (materials for new electronic properties) and QSIT (Quantum science and engineering) have modules which incorporate research on graphene (each about 400 kCHF per year).

Scientific output	
Publications :  	
Patents	
Applicants	6
Inventors	3
Research institutes / Number of PIs	
École polytechnique fédérale de Lausanne (EPFL)	5
Paul Scherrer Institute (PSI)	2
Swiss Federal Institute of Technology Zurich (ETH Zürich)	3
Swiss Federal Laboratories for Materials Science and Technology (EMPA)	3
University of Basel	2
University of Bern	1

University of Geneva	5
University of Zürich	2
Research funding	
Total number of PIs	23
Total number of active research groups*	8
National research funding per year for 2011 (in k€)	3278
SMEs and Industrial R&D activity	
Research Infrastructures	
Future activities	

* *Only data submitted via web portal www.graphene-flagship.eu*

UNITED KINGDOM

Country	United Kingdom
Contact (name, email)	Professor Vladimir Falko v.falko@lancaster.ac.uk Professor Andrea C. Ferrari acf26@eng.cam.ac.uk
Organisation	Lancaster University University of Cambridge

Summary of scientific activities and funding

There are more than 80 full-time permanent academics, 100 postdocs and 200 students in more than 40 groups of various sizes working in Physics, Materials, Chemistry, Engineering and Communications departments of British Universities. The largest centre is in Manchester. These groups are equipped for manufacturing graphene using exfoliation techniques and sonication in liquids; X-ray, ARPES and STEM studies (in particular, using light sources at Rutherford-Appleton Laboratory and Daresbury Laboratory); nanofabrication using the already existing Nano-Centres (such as in Manchester, Cambridge, Leeds, UCL, Southampton); optical characterisation (such as Raman and pump probe spectroscopies); transport studies of devices in ambient condition, at low temperatures and strong magnetic fields (for this collaborations with the HMFL in Nijmegen and Grenoble HMFL are used); theoretical modelling. Collaborations within the country include several inter-institutional grants, distribution of samples by Manchester-based Graphene Industries Ltd, and knowledge transfer, joint Manchester-Lancaster Doctoral Training Centre NOWNANO; joint Exeter-Bath Graphene Centre, Cambridge NanoDTC centre.

The main funding programmes:

1. Science & Innovation Awards for ‘Maximising impact of graphene research on innovation through physics, chemistry and engineering’ (Manchester and Lancaster Universities) and ‘Graphene Centre’ (Exeter and Bath): €15M in 2009-2014.
2. A £50 million Global Graphene Research and Technology Hub, based upon excellence centres in Manchester, Cambridge, Lancaster, Exeter, Bath, Oxford and Durham universities and Imperial College London.
3. Several EPSRC funded grants.
4. Several grants funded by The Royal Society, The Royal Academy of Engineering, The Leverhulme Trust, Integrated Knowledge Centres.

Private sector:

British Aeorspace Engineering is interested in ultra-strong light materials based on graphene.

Azko Nobel – paints and caotings

Varta – graphene enhanced batteries

Domino Ltd – printed electronics

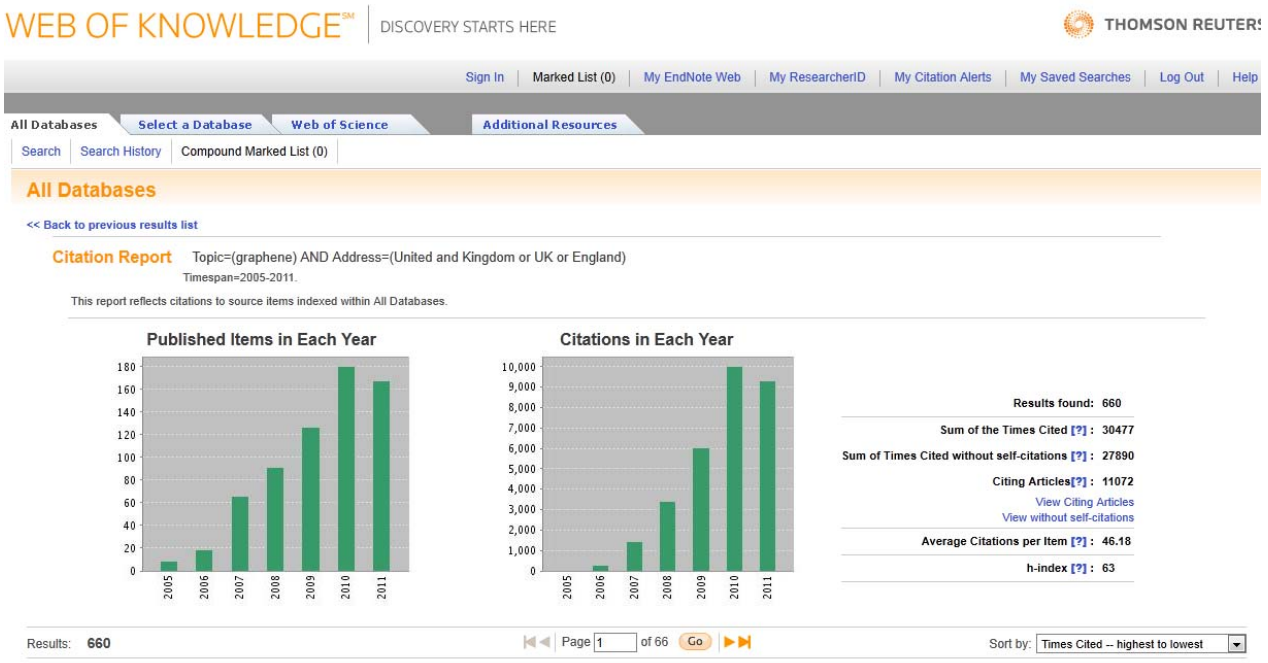
Cambridge CMOS Sensors – development of NEMS

Aixtron LTd-CVD deposition systems and SiC

Four SMEs: Graphene Industries Ltd (Manchester), Durham Graphene Science Ltd and Haydale Ltd (Port t Talbot) sell graphene-based research products; Camlase ltd (Cambridge) sells photonic devices based on graphene.

Scientific output

Publications :



Patents	
Applicants	14
Inventors	11
Research institutes / Number of PIs	
Cardiff University	1
Durham University	1
Heriot-Watt University, Edinburgh	1
Imperial College London	6
King's College London	1
Lancaster University	2
Newcastle University	1
Open University, Milton Keynes	1
Queen Mary, University of London	1
Queen's University of Belfast	2
Science and Technology Facilities Council (STFC)	1
Swansea University	1
University College London	3
University of Bath	2
University of Bristol	2
University of Cambridge	6
University of Edinburgh	3
University of Exeter	4
University of Leeds	1
University of Liverpool	1
University of Manchester	5

University of Nottingham	2
University of Oxford	3
University of Plymouth	2
University of Salford	2
University of Sheffield	3
University of Southampton	3
University of Surrey	2
University of Sussex	1
University of Warwick	1
University of York	1
Research funding	
Total number of PIs	66
Total number of active research groups*	51
National research funding per year for 2011 (in k€)	6638
SMEs and Industrial R&D activity	
Private sector in the UK has focus on several directions of among graphene applications: British Aeorspace Engineering is interested in ultra-strong light materials based on graphene. Azko Nobel – paints and caotings Varta – graphene enhanced batteries Domino Ltd – printed electronics Cambridge CMOS Sensors – development of NEMS Aixtron LTd-CVD deposition systems and SiC	

* *Only data submitted via web portal www.graphene-flagship.eu*

Four SMEs: Graphene Industries Ltd (Manchester), Durham Graphene Science Ltd and Haydale Ltd (Port t Talbot) sell graphene-based research products; Camlase ltd (Cambridge) sells photonic devices based on graphene. National Physical Laboratory Ltd uses graphene for metrology applications.
Research Infrastructures
The following large-scale infrastructure may be open for external user: Diamond synchrotron light source has several X-ray and ARPES lines suitable for graphene characterisation. STM facility in London Nanoscience Centre (UCL and Imperial College). From 2012, new JOEL nanofabrication facility in the Lancaster Quantum Technology Centre; nanofabrication in the Nanocentre in Southampton. Ultra-low temperature facility in the Lancaster Quantum Technology Centre. National Physical Laboratory in Teddington – extreme metrological measurements.
Future activities
A £50 million Global Graphene Research and Technology Hub, to develop commercial uses for graphene. The Hub will leverage private sector investment and help develop a home grown high-tech industry. A competition to establish and operate the graphene hub will be launched by the EPSRC/TSB subject to the approval of the business case.

Annex C : Industry, SMEs and private sector

Company	Website	Country	Activity
Crystalsol	http://crystalsol.at	Austria	Electronics, optoelectronics, optics
Profactor GmbH	http://www.profactor.at/	Austria	Energy, materials
Zumtobel Group	http://www.zumtobelgroup.com	Austria	Lighting
AGC Flat Glass	http://www.agc-glass.eu/	Belgium	Materials, glasses
IMEC	http://www2.imec.be/	Belgium	R&D Center
Nanocyl	http://www.nanocyl.com/	Belgium	Materials, carbon nanotubes
SOLVAY	http://www.solvay.com/	Belgium	Chemicals, coatings
QuantumWise A/S	http://www.quantumwise.com/	Denmark	Software, simulation tools
Elcogen	http://elcogen.ee	Estonia	Energy
Skeleton Technologies	http://skeletontech.com	Estonia	Energy
Aivon Ltd	http://www.aivon.fi	Finland	Electronics, optoelectronics, optics, sensors
Diarc Ltd	http://www.diarc.fi	Finland	Materials, coatings
Nokia	http://nokia.com	Finland	Electronics, optoelectronics, optics
PicoSun Ltd	http://picosun.com/	Finland	Equipment and tools
Renesas Mobile Corporation	http://www.renesas.eu	Finland	Electronics, optoelectronics, optics
VTT Technical Research Centre	http://www.vtt.fi	Finland	R&D Center
Arkema	http://www.arkema.com/	France	Chemicals
CEA	http://www.cea.fr/	France	R&D Center
Institut de la Vision/Pixium	http://www.institut-vision.org/	France	Health
ISORG	http://www.isorg.fr/	France	Electronics, optoelectronics, optics
NANOTIMES	http://www.nanotimes-corp.com/	France	Software, simulation tools
Saint Gobain	http://www.saint-gobain.com/	France	Materials
Sanofi Aventis	http://en.sanofi.com/	France	Health, pharamaceutics
Thales	http://www.thalesgroup.com/	France	Electronics, optoelectronics, optics
AMO GmbH	http://www.amo.de/	Germany	Electronics, optoelectronics, optics
Alcatel-Lucent	http://www.alcatel-lucent.com	Germany	Electronics, optoelectronics, optics
BASF SE	http://www.basf.com/	Germany	Chemicals, coatings, materials
Bayer AG	http://www.bayer.com/	Germany	Health, pharamaceutics
Bosch GmbH	http://www.bosch.com/	Germany	Consumer products, automotive, energy
Infineon	http://www.infineon.com/	Germany	Electronics, optoelectronics, optics
LG Electronics	http://lg.com/	Germany	Electronics, optoelectronics, optics

Qualcomm GmbH	http://www.qualcomm.fr/	Germany	Electronics, optoelectronics, optics
Raith GmbH	http://www.raith.com/	Germany	Equipment and tools
MOBIChem	http://www.mobichem-sci.com/	Israel	Materials, polymers
FIAT	http://fiat.com/	Italy	Transport
ST Microelectronics	http://www.st.com/	Italy	Electronics, optoelectronics, optics
Thales Alenia Space	http://www.thalesgroup.com/	Italy	Aerospace
Glantreo	www.glantreo.com/	Ireland	Materials, graphene
Intel	www.intel.com/	Ireland	Electronics
HP	www.hp.com/	Ireland	Electronics, optoelectronics, optics, sensors
Henkel	www.henkel.com/	Ireland	Materials, chemicals
Samsung	http://samsung.com	Korea	Electronics, optoelectronics, optics
Applied Nanolayers		Netherlands	
Carl Zeiss	http://www.zeiss.com/	Netherlands	Electronics, optoelectronics, optics
Dow Chemical	http://www.dow.com/	Netherlands	Chemicals, coatings
DSM	http://www.dsm.com/	Netherlands	Health, pharamaceutics
Hauzer Techno coating	http://www.hauzer.nl/	Netherlands	Equipment and tools
NXP	http://www.nxp.com/	Netherlands	Electronics, optoelectronics, optics
Philips	http://philips.com	Netherlands	Electronics, optoelectronics, optics
Stratom	http://www.stratom.com/	Netherlands	Engineering products
Abalonyx AS	http://www.abalonyx.no/	Norway	Materials
Epi-Lab	http://www.epi-lab.com/	Poland	Materials
KGHM Miedz SA	http://www.kghm.pl/	Poland	Materials
PSE Operator SA	http://www.pse-operator.pl/	Poland	Energy
Seco-Warwick Poland	http://www.secowarwick.com/	Poland	Equipment and tools
DDS DIAGNOSTIC	http://www.ddsdiagnostic.ro/	Romania	Health, pharamaceutics
Sitex 45 SRL	http://microsisteme.ro/	Romania	Electronics, optoelectronics, optics
Danubia NanoTech	http://www.danubiananotech.com/	Slovakia	Materials
Acciona	http://www.acciona.com/	Spain	Energy
Airbus	http://www.airbus.com/	Spain	Transport
Avanzare	http://www.avanzare.es/	Spain	Graphene synthesis
Cuadros Electricos Nazarenos	http://www.cenazarenos.com/	Spain	
Ferroatlantica	http://www.ferroatlantica.es/	Spain	Materials
Fertiberia SA	http://www.fertiberia.es/	Spain	Chemicals
Geolen Ingenieria SL	http://www.geolen.es/	Spain	Engineering
GRAnPH Nanotech	http://www.granphnanotech.com/	Spain	Graphene synthesis

Graphenea S.A.	http://www.graphenea.com/	Spain	Graphene synthesis
IBERDROLA SAU	http://www.iberdrola.es/	Spain	Energy
Indra	http://www.indracompany.com/	Spain	Engineering, energy, transport,
INNOVARCILLA	http://www.innovarcilla.es/	Spain	Materials, ceramics
MMR GROUP	http://www.mmrgrp.com/	Spain	Engineering
NANOCONECTA, S.L.		Spain	
Nanoinnova Technologies	http://www.nanoinnova.com/	Spain	Equipment and tools
Nanotec Electronica	http://www.nanotec.es/	Spain	Equipment and tools
Nanozar SL	http://www.nanozar.com/	Spain	Materials
Repsol	http://www.repsol.com	Spain	Energy
Sensing & Control Systems S.L.	http://www.sensingcontrol.com/	Spain	Software, telecommunications
Tecnalia	http://www.tecnalia.com/	Spain	R&D Center
Técnicas Reunidas S.A.	http://www.tecnicasreunidas.es/	Spain	Engineering
Tecnove Security	http://www.tsecurity.es/	Spain	Security
TELEVES SA	http://www.televes.com/	Spain	Equipment and tools
Tindaya Renovables, SL	http://www.empresasnuevas.es/	Spain	Energy
Tolsa	http://www.tolsa.com/	Spain	Materials
Volvo	http://volvo.com	Sweden	Transport
AIXTRON Ltd	http://www.aixtron.com/	United Kingdom	Equipment and tools
AkzoNobel	http://www.akzonobel.com/	United Kingdom	Chemicals, paints, coating
Cambridge CMOS Sensors	http://www.ccmoss.com/	United Kingdom	Electronics, optoelectronics, optics, sensors
CamLase Ltd	http://camlase.com/	United Kingdom	Electronics, optoelectronics, optics, sensors
Domino Ltd	http://www.domino-printing.com/	United Kingdom	Materials, printing
Durham Graphene Science Ltd	http://durhamgraphene.com/	United Kingdom	Graphene synthesis
Graphene Industries Ltd.	http://grapheneindustries.com/	United Kingdom	Graphene synthesis
Haydale Limited	http://www.haydale.com/	United Kingdom	Graphene synthesis
Oxford Instruments	http://www.oxinst.com/	United Kingdom	Equipment and tools
Varta	http://www.varta.com/	United Kingdom	Energy
IBM	http://ibm.com	United States	Business services, IT
Texas Instruments	http://ti.com	United States	Electronics

Annex D: Acronyms and Abbreviations

AKA	Academy Of Finland
BMBF	Bundesministerium für Bildung und Forschung - Germany
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives - France
DFF	Danish Council for Independent Research
DFG	Deutsche Forschungsgemeinschaft - Germany
DNRF	Danish National Research Foundation
EPSRC	Engineering and Physical Sciences Research Council - UK
FCT	Fundação para a Ciência e a Tecnologia - Portugal
FNRS	Fonds de la Recherche Scientifique - Belgium
FOM	Foundation for Fundamental Research on Matter - Netherlands
FORTH	Foundation for Research and Technology – Hellas - Greece
FWF	Austrian Science Fund
GACR	Grantová agentura České republiky – Czech Republic
MICINN	Ministerio de Ciencia e Innovación - Spain
OTKA	Hungarian Scientific Research Fund
SNF	Schweiz. Nationalfonds - Switzerland
STW	Technologiestichting - Netherlands
VR	Swedish Research Council