PROJECT FINAL REPORT

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Project acronym: MERGING

Project title: Membrane-based phonon engineering for energy harvesting

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

4.1 Final publishable summary report

This section must be of suitable quality to enable direct publication by the Commission and should preferably not exceed 40 pages. This report should address a wide audience, including the general public.

The publishable summary has to include **5 distinct parts** described below:

- An executive summary (not exceeding 1 page).
- A summary description of project context and objectives (not exceeding 4 pages).
- A description of the main S&T results/foregrounds (not exceeding 25 pages),
- The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages).
- The address of the project public website, if applicable as well as relevant contact details.

Furthermore, project logo, diagrams or photographs illustrating and promoting the work of the project (including videos, etc…), as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

4.1.1 Executive summary

We report on the activities carried out within the FP7 project MERGING “Membrane-base phonon engineering for energy harvesting”, contract nr. 309150. The main objective of the project was to enable nm-scale control of energy flow to impact (a) on-chip harvesting of thermoelectricity and (b) optimising the thermal management of heat flow in heterogeneous integration in nanoelectronic applications. It was a cooperative effort of six partners who brought their expertise to MERGING which benefited from the world-class theoretical expertise of the Max-Planck-Institute for Polymer Research (MPI) in electronic and phononic band structure calculations, the pioneering thermometry expertise of the Institut Neel (CNRS), the outstanding nanofabrication and nanoelectronics expertise of the Technical Research centre of Finland (VTT), the world-leading molecular beam epitaxial growth of GeMn thin films supported by cutting-edge high-resolution electron microscopy to study down to the nanometre resolution the materials undergoing optimisation, both at the CEA Materials Division. CIDETE contribute their long-standing expertise in thermoelectric modules and ICN brought their leading expertise in confined phonons, light scattering and phononic crystals.

The driving force was the proof of concept of using phonon engineering, the engineering of lattice vibrations, to obtain materials with as low thermal conductivity as possible suitable for harvesting energy in the form of thermoelectric generation. The ambition was the physical realisation of a laboratory-scale thermoelectric (TE) module based on the concept of ultra-thin membranes, akin to nanoscale electro-mechanical systems, to power a low power gadget. The project pushed technological developments well beyond the state of the art, as well as our understanding, on several fronts: material growth and nanostructuring, theoretical models and calculations, novel thermal properties methods and measurement techniques, process development to realise a TE generator module with appropriate circuitry. It advanced dramatically our understanding of heat transport in nanoscale materials, interfaces and surfaces, re-examined the concept of electron crystal-thermal glass as the key to reduce thermal conductivity. The project ran smoothly over the three years achieving almost all of its goals, sometimes exceeding expectations although the final milestone could not be reached since the latest material developments came to fruition close to the end of the project.

MERGING leaves for the scientific community a rich inheritance of technology and know-how and opens doors for future projects. We showed that, even for such small amount of material (few 1000s μm^3 and despite the high surface to volume ratio, the thermal conductivity can be between 20 and 50 times lower than in the bulk.

We demonstrated that using silicon ultrathin doped membranes a thermoelectric device can be fabricated and operated as a cooling device at room temperature with a ZT between 0.2 to 0.5. Likewise, a GeMn-Ge membrane-based device promises to reach a similar level since p- and n-doping were demonstrated just at the end of the project.

The results obtained in MERGING bring closer to reality the possibility to power low energy devices for, e.g., the Internet of Things using compact, environmentally friendly and relatively low cost TE modules. Much remains to be done to take this research from the achieved technology readiness level 1 (proof of concept) to the next stages towards a new compact energy technology.

4.1.2 Summary description of project context and objectives

The project came about in the quest for efficient, compact and ideally autonomous energy saving devices driven by the need to lower the power consumption of electronic and related devices making use of the heat dissipated during operation through an integrated thermoelectric device.
At the start we had known that the phonon dispersion relation was sensitive to dimensionality, external stress and to structuring as in phononic crystals. In particular the modification of the dispersion relations affected the lower lying phononic bands and therefore we expected that with a suitable material design the acoustic phonon bands could be sufficiently modified to lower the thermal conductivity. We also knew that by engineering not only the hypersonic (GHz) phonons dispersion but also THz phonons, which should be sensitive to surface conditions and to perturbations in a size scale comparable to the extent of their wavefunction – a few nm- we could also influence the thermal conductivity. Only that the path to advance reliably phonon engineering was not clear and the techniques, experimental and theoretical, needed essential advances if we were going to achieve meaningful energy harvesting.

Thus, our ***project concept*** was based on minimising the thermal conductance and/or thermal conductivity by phonon engineering, thereby advancing the knowledge base on the potential offered by lower dimensionality, in general, and nanostructuring, in particular. The project realisation relied in know-how coming from solid-state and low-temperature physics, from crystal growth and thin film technologies, from high precision stable instrumentation and from thermoelectric module engineering.

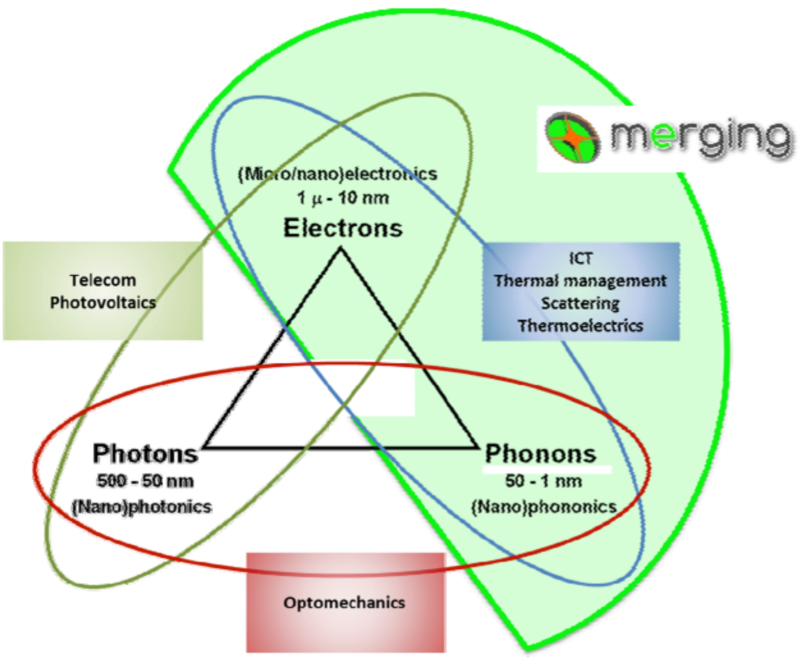


Figure 1. The context in which the MERGING project is embedded.

Thus, the ***main objective*** of MERGING was to enable nm-scale control of energy flow to impact (a) harvesting on-chip harvesting of thermoelectricity and (b) optimising the thermal management of heat flow in heterogeneous integration in nanoelectronic applications.

To achieve our objectives we focused on silicon-compatible materials and technologies from material design all the way to a prototype device for testing in an industrial environment. In practice this involved research on phonon band structure control in Si, GeMn and, to a lesser degree, in strontium titanate (ST), barium strontium titanate (BST) or strontium titanate niobate (STNb) in the form of membranes and supported ultrathin films going from a model system to device-like structures. Beyond the state-of-the-art thermal conductance and conductivity measurement methods were part of this project. To understand thermal energy transport a thorough theoretical program was an integral part in the MERGING research plan.

The project structure is shown in figure 2. The work was structured in six technical work packages, one on Exploitation and Dissemination and one on project coordination.

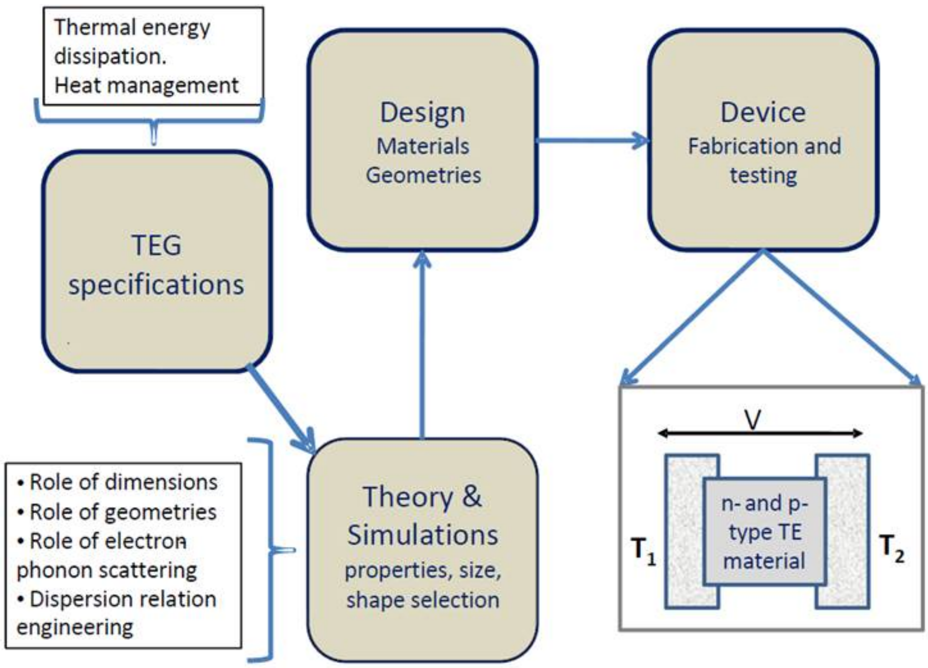


Figure 2. Structure of MERGING.

4.1.3 Main Science and Technology Results

Highlights of project results

1) A laboratory-scale fully integratable TE device module was realised using planar technology with a compact design, full flexibility for the design of the TE pairs of legs and using non-toxic materials as shown in Figure 3.

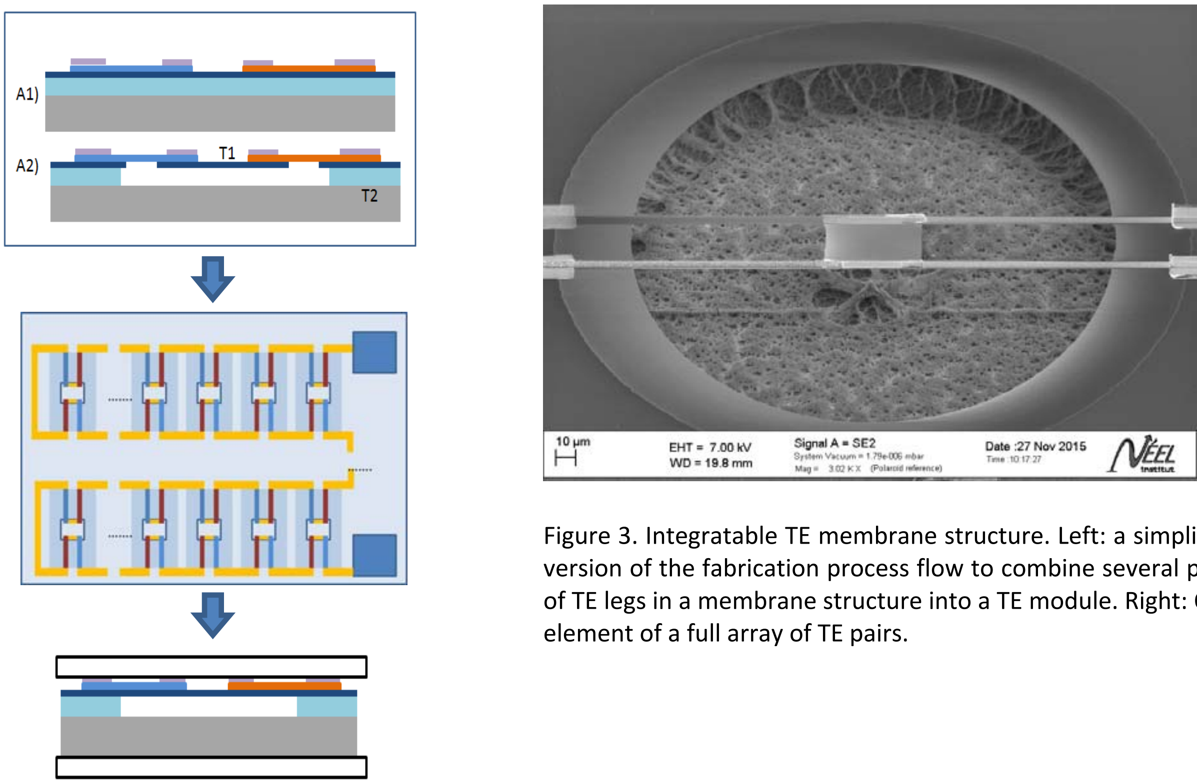


Figure 3. Integratable TE membrane structure. Left: a simplified version of the fabrication process flow to combine several pairs of TE legs in a membrane structure into a TE module. Right: One element of a full array of TE pairs.

2) The manufacture path of a processor module to integrate with the MERGING TE module into an autonomous sensor powered by harvesting technology was tested and demonstrated with a commercial TE module equipped with a power module processor designed to work with the voltages generated by the MERGING materials. The electronic module concept is illustrated in Figure 4. The power processor module is based on a power pump structure

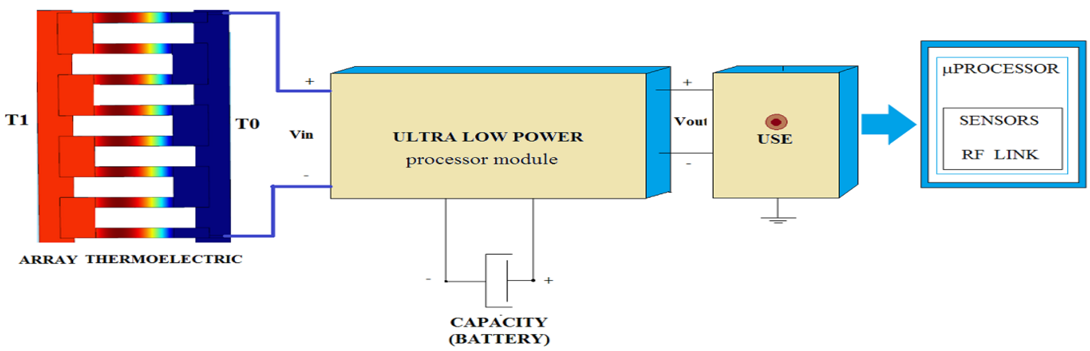
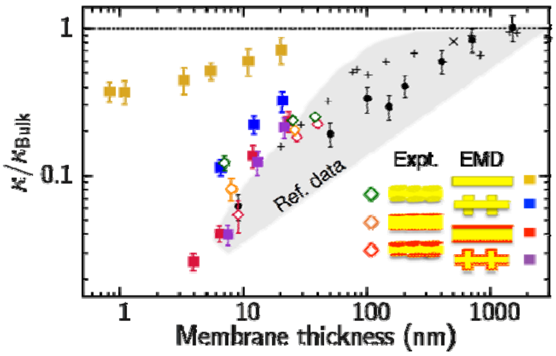
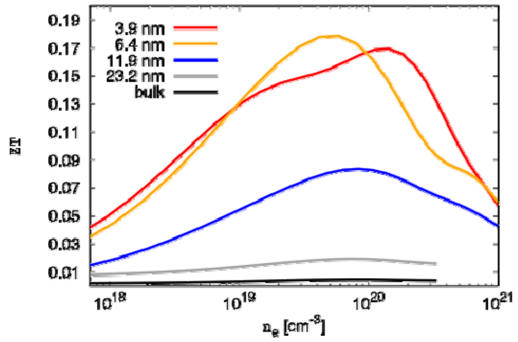


Figure 4: Electronic module concept to deal with low voltages. The ultralow power processor module is able to t signal of 7 mV and convert it to a 5 V one.

3) Based on the earlier simulations of the reduction of the thermal conductivity in ultra-thin silicon membranes, our latest calculations suggest a well-defined strategy to design the phononic and thermal properties of silicon membranes. In particular, we have identified the ideal thickness of silicon membranes that provides the highest thermoelectric figure of merit (ZT~0.2 at room temperature).





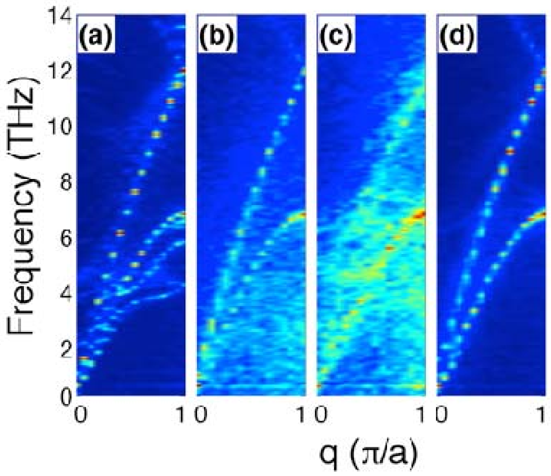


Figure 5. Illustration of the theoretical work undertaken in MERGING. Top Left: A reduction of the thermal conductivity in silicon membranes was calculated incorporating surface resonances and mass scattering. Here the good agreement between calculated data points and experimental ones are shown. Bottom left: Dispersion relation combining surface resonances and mass scattering. Top right: Calculated ZT in Mn5Ge3/Ge heterostructures as a function of carrier concentration.

4) Realisation of an electron-crystal phonon-glass in GeMn/Ge. Encouraging values of thermal conductivity were obtained in sample with 10% Mn concentration, which under electron microscopy investigation exhibited crystalline GeMn clusters embedded in the crystalline Ge matrix. By means of EELS observations we proved that manganese is present only inside clusters since the Mn concentration in the Ge matrix is below the detection limit of about 0.5%. This, together with a thermal conductivity reduction of a factor of 50 with respect to the bulk, pointed clearly to the realisation of a highly desirable electron crystal-phonon glass material for TE generation. Towards the end of the project n- and p-doping was achieved up to concentrations of 10^{19} cm^{-3}. ZT was fund to climb up to 0.25 at RT in doped GeMn.

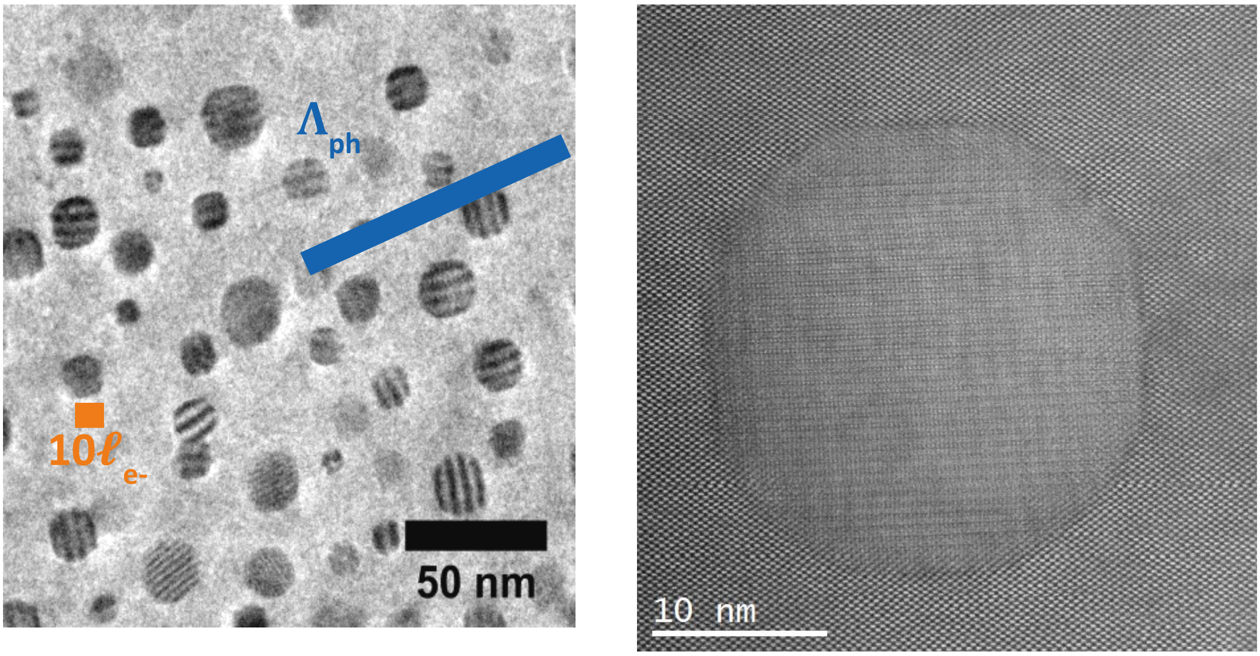


Figure 6. High-resolution transmission electron microscopy of several nanoclusters in a Ge matrix (left) and of a nanocrystal in a Ge matrix (right).

5) On experimental methodology the consortium has made three important contributions to nano-scale thermal characterisation: (i) development and demonstration of an efficient thermal conductivity measurement technique based on 3-omega applied to very thin film of semiconductors; (ii) development and demonstration of a contactless technique dedicated to the measurement of thermal properties of ultra-thin Si membranes based on light scattering and iii) development of thermoelectric measurement (Seebeck and electrical conductivity) suitable for thin films.

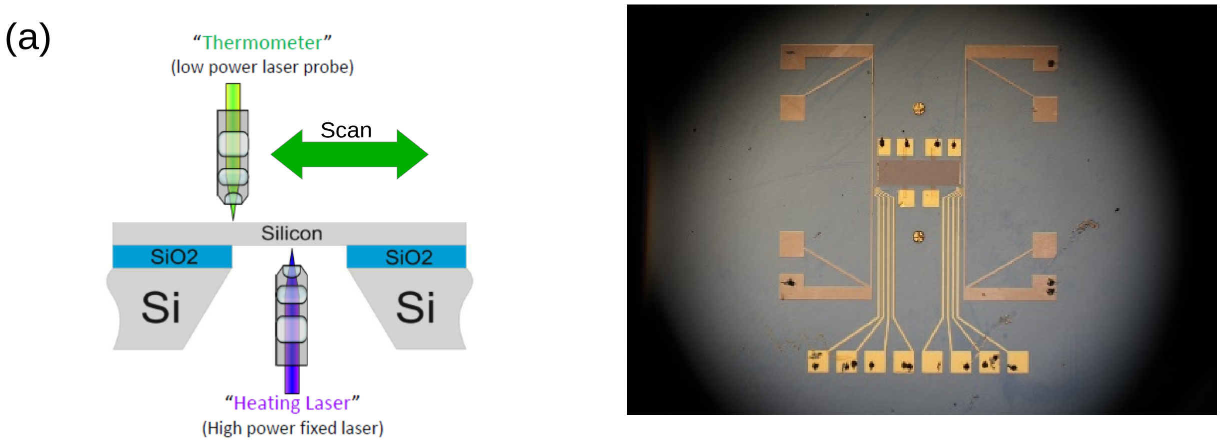


Figure 7. Examples of the experimental methods developed in MERGING to measure thermal conductivity. Left: schematics of the contactless Two-laser Raman Thermometry. Right: Layout of contacts for Seebeck measurements.

6) A series of proof-of-concept devices in ultra-thin Si membranes were fabricated, which hold the promise of compact cooling devices. These have benefited from the low dimensionality and the process is microelectronics-compatible. The ZT at room temperature of one pair of legs is ZT between 0.2 and 0.5.

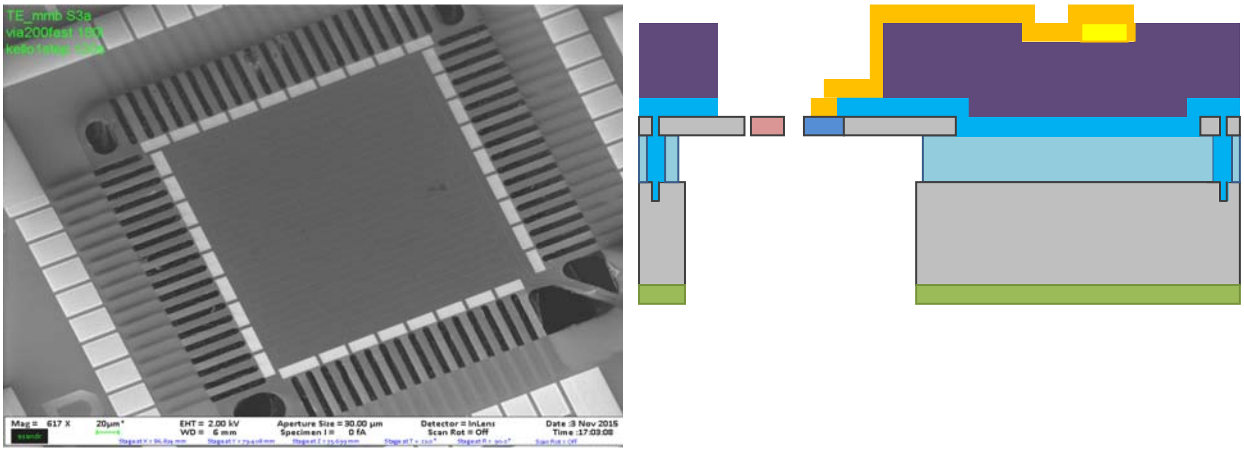


Figure 8. Left: Image of one Si membrane TE device with several pairs of legs. Right: Schematics of the cross sectic the membrane TE device.

Science and Technology results per work Package

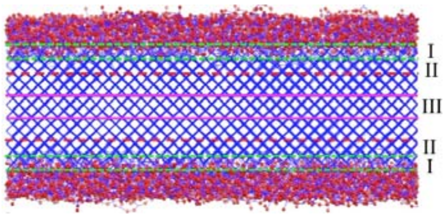
For clarity, the work carried out in MERGING is described below not necessarily following the WP numbering.

WP2 – Theory and Simulation

The objectives of this workpackage were to develop theory to support the structural, electronic and phononic characterization of nanostructured GeMn:Ge as well as thermal transport in silicon, strontium titanate and GeMn:Ge membranes. Furthermore calculation of ZT in membrane-based devices and Finite Element calculations of phonon properties of membranes (>50 nm thick) were among its remit. The MPI led this workpackage and used a multi-scale approach to structural and phononic properties of materials and nanodevices. In particular it deployed Ab initio calculations (Density Functional Theory), Neural Network potentials with DFT quality, Large-scale Molecular Dynamics simulations and Finite Elements simulations.

We fitted a neural network potential that reproduces the vibrational properties of several different phases of GeMn alloys with different stoichiometry with accuracy comparable to first-principles methods (Density Functional Theory). The potential is transferable also to Ge-Mn_5Ge_3 interfaces and superlattices. This potential allows the prediction of the structure and the calculation of the thermal conductivity of nanostructured GeMn membranes.

Theoretical and experimental verification of the role of the native oxide on thermal conductivity of thin Si membranes was successfully correlated.



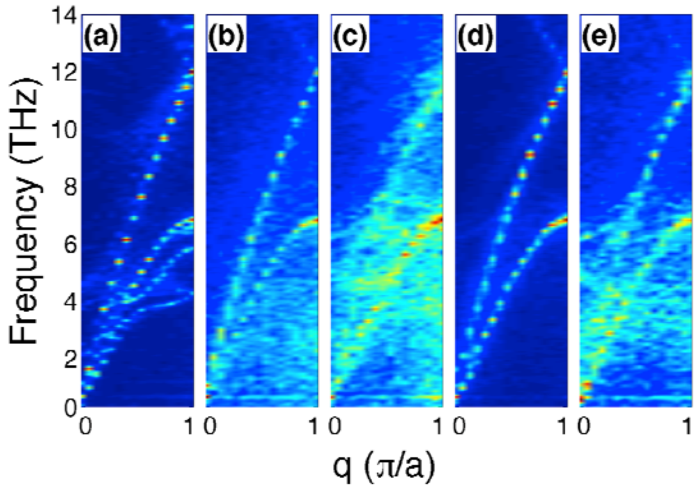


Figure 9. Dispersion relations of a pristine membrane (a), of an oxidized membrane resolved by region I, II, III (b-d) and of an oxidized membrane with Si vacancies in region I (e).

Calculation of ZT for membrane-based devices

Two complementary approaches were followed:

1- We have calculated the thermoelectric figure of merit of extended silicon membranes, computing the electronic transport properties (conductivity, Seebeck coefficient and electronic thermal conductivity) using density functional theory and the Boltzmann transport equation.

2- We have set up a tool to perform the thermoelectric characterization of membrane-based devices, using density functional tight binding (DFTB) and Green's functions.

Using the DFT-BTE approach we have computed the thermoelectric figure of merit of membranes with different thicknesses. We have identified an optimal thickness of 6-7 nm for which a maximum figure of merit of at most 0.18 can be obtained (Fig. 9). Below this optimal thickness we observe a degradation of the electronic conductivity, due to electronic confinement, while, in turn, no significant increase of the Seebeck coefficient is observed.

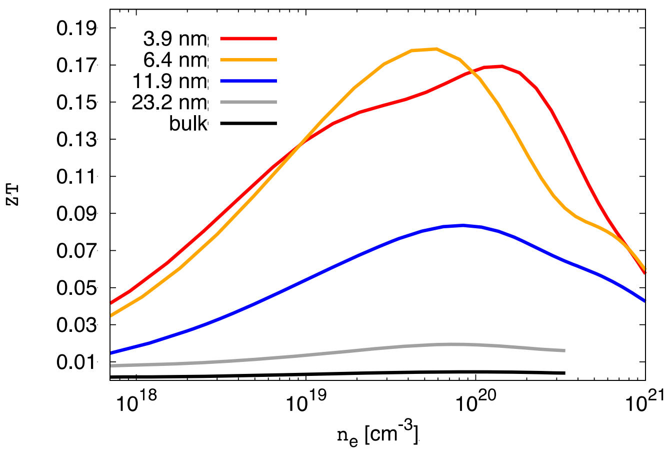


Figure 10. Thermoelectric figure of merit of oxidized silicon membranes of different thickness as a function of the concentration of carriers (electrons).

Phosphorous doping at high concentration, above 10^{18} cm^{-3}, leads to the formation of an impurity band, which modifies the electronic density of state of silicon membranes. The presence of impurity bands was predicted to enhance the Seebeck coefficient, far higher than that computed by considering the band structure of pristine silicon[2]. We have computed the Seebeck coefficient of

[2] H Ikeda and F Salleh, "Influence of Heavy Doping on Seebeck Coefficient in Silicon-on-Insulator," *Applied Physics Letters* 96, 012106 (2010).

phosphorus and boron-doped 5 nm thick Si membranes using DFT-BTE. These calculations show that the Seebeck coefficient may be indeed largely enhanced, however only for a narrow range of chemical potential.

We performed calculations of electronic and phononic transport in silicon membranes devices using the density functional tight binding and Green's function approach.

These calculations suggest that ZT of about 0.1 can be achieved in ultrathin silicon membranes for devices of the order of few tens of nm (Fig. 10), regardless of oxidation. The reason is that the observed beneficial effect of oxide layers on thermal conductance is compensated by a reduction of the electronic conductance. This result is consistent with the one obtained by DFT-BTE. The electronic transmission in the central part of oxidized membranes is indeed affected by dipolar scattering from the surface layer. Calculations for larger membranes would be necessary to see whether the two have effect have different length scales and an optimal size can be found.

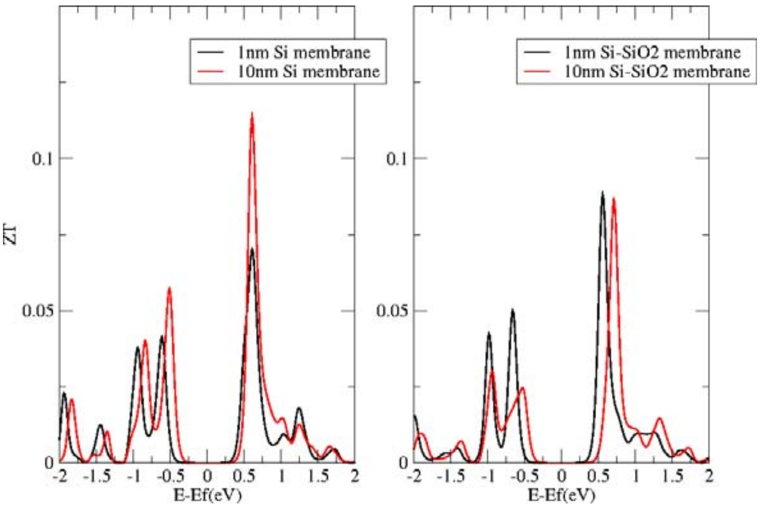


Figure 11. Thermoelectric figure of merit of Si membrane devices, in which the non periodic part considered is 1 and 10 nm, respectively.

Thus, the potential of membrane devices was successfully verified by simulations.

WP3 – Characterisation and Tool Design

The approach and aims of this workpackage were to implement a complete experimental setup devoted to the precise measurement of thermoelectric properties of Merging materials, which were mainly thin film of nanostructured material, especially very thin membrane difficult to handle as well as phononic crystal membranes. CNRS led this workpackage and ICN and VTT contributed to it.
It was necessary to adapt measurement techniques of thermal conductivity in various TE materials and suspended membranes using the 3-omega technique. As a cross-check and for specific samples exhibiting an optical phonon Raman signal, a contactless technique particularly adapted to ultra-thin membranes had to be developed: One and Two-laser Raman thermometry, which yielded temperature maps and allowed the extraction of thermal conductivity with sub-micrometre resolution. Measurements of electrical properties in thin film are notoriously difficult and even more so thermal properties if high accuracy is required. Thus, three methods were developed: (i) an efficient thermal conductivity measurement technique based on 3-omega applied to very thin film of semiconductors; (ii) a contactless technique dedicated to the measurement of thermal properties of ultra-thin Si membranes based on light scattering and iii) thermoelectric measurement (Seebeck and electrical conductivity) suitable for thin films. The experimental suite of methods allowed then

the measurements of ZT values in nanosystems (membrane, nanostructured semiconductors). One example of how these methods were used is illustrated with the study of GeMn thin films.

Electrical and ZT measurement on TE materials

The thermoelectric performances of GeMn thin films having various Mn concentration were measured and the optimum Mn concentration found to be 10%. The increase of ZT can be as high as a factor of 10 to 20 compared to bulk material having the same doping level. This increase is caused by the drastic diminution of the thermal conductivity studied for different % Mn thin films. The outstanding performance permits the use of these materials in real thermoelectric module. This step necessitates technological developments in order to increase the electrical conductivity of the GeMn layers and develop n-type doping. This doping (p and n type) has been successfully done by CEA using ion implantation. This has significantly improved the electrical conductivity of the GeMn samples and permit us to contemplate GeMn thin film with ZT value of ~ 0.5. The data of GeMn are summarized in table 1, and forms part of the milestone MS10.

Table 1: Summary of ZT values obtained for the best Mn concentration (10%). For a comparison few result from the literature have been added in italic and a projection for optimised GeMn in bold.

	%Mn	$T_{annealing}$	S ($\mu V.K^{-1}$)	σ ($\Omega^{-1}cm^{-1}$)	k	ZT
#REC12	10	709	185	97	3.2	0.05
#REC13 *doped 10^{18} cm^{-3}*	10	757	205	200	3	0.1
Ge bulk doped 10^{18} cm^{-3}	*X*	*X*	*~ 300*	*~ 100*	*60*	*0.00045*
Bi_2Te_3	*X*	*X*	*~200*	*1000*	*~ 1.5*	*~ 1*
GeMn doped 10^{19} cm^{-3}	**10**	**750**	**200**	**1000**	**3**	**~ 0.5**

WP4 – Device Concept Verifications

The mission of this workpackage was to fabricate ultra-thin free-standing Si, Ge and STO:Nb membranes to increase the ZT values, to reduce the spatial overlap of electron conduction and phonon thermal transport. It was led by VTT. The WP4 was directly linked to WP2 for comparison of data with the calculations. The overarching aim was to reduce the phonon transmission in membrane-based thermoelectric system to below 1 W/mK. To achieve these ambitious aims, three approaches were attempted: (i) fabrication of membranes for characterisation and optimisation of thermal properties, (ii) fabrication of phononic crystals and (iii) fabrication of structures for device testing.

Technology was developed to fabricate strain-free and strained ultrathin free-standing large area Si membranes with thickness ranging between 50 and 6 nm which are ideal for thermal conductivity studies. In particular, we demonstrated the reduction of thermal conductivity in Si membranes by a factor of 16 compared to bulk value, which by introducing targeted surface roughness is further lowered a further 25-100 times with respect to the bulk value. As part of progressing towards a TE device, we have achieved a fully consistent thermoelectric characterisation of silicon membranes in device-like configuration (open system).

A very important outcome has been the verification of **the role of the native oxide** on thermal conductivity of **ultra-thin Si membranes**. This has been investigated both experimentally and using computational modelling (ICN, VTT, MPI). The thermal conductivity decreases by a factor of 15 in 10 nm thick membranes, the effect mainly arising from the thin native oxide and surface roughness.

In 2-dimensional **phononic crystals**, we investigated the effect of **increasing disorder** on thermal conductivity of a 250 nm thick silicon membrane (ICN). The samples were fabricated at ICN and characterisation was carried out by asynchronous optical sampling (ASOPS) and Raman thermometry. The results show that, first, the thermal conductivity decreases by a factor of 20 in comparison to a similar but unpatterned membrane and secondly, increasing disorder supresses the higher harmonics of the phonon modes in the membrane, as expected, but does not affect the total thermal conductivity.

Two further technological developments are noteworthy:

(i) A self-assembly process of diblock co-polymers for high-density matrices with very small dimensions suitable for smaller periodicity phononic crystals (see figure 12). The pattern transfer stage is under development.

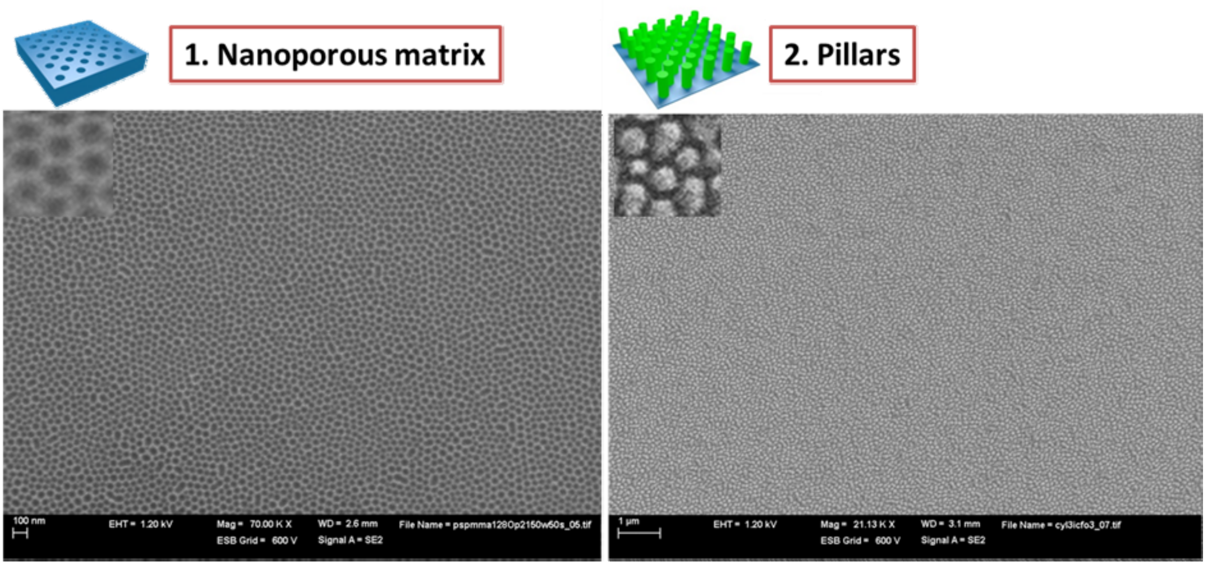


Figure 12. Preparation of hexagonal periodic arrays via BCP self-assembly bottom-up approach. Polystyrene mesoporous matrix (left) and polystyrene pillars (right) on 250 nm thick Si membrane.

(ii) Concerning strontium titanates, we have developed a low-stress co-sputtering process for STO:Nb and established an enhanced Seebeck coefficient for thin film. The latter is still under investigation.

The work towards TE devices was carried out with Si membranes. The Si modules are based on highly doped single crystalline p- and n-type beams patterned into a 40 nm thick Si membrane. The beams form the TE generator leg pairs and support the central membrane part on which they are electrically connected. A SEM image of a Si membrane TEG is shown in figure 8 above.

The electrical properties of the membranes were measured in a magnetic field in the van der Pauw configuration. The thermal conductivity was obtained from Raman thermometry. The results for the doped 40 nm thick membranes are given in Table 2. The Seebeck coefficients were extracted from two different structures using optical or electrical heating. Both approaches gave a Seebeck coefficient of 400-500 µV/K for one p-n leg pair around room temperature. The modules were preliminary tested by heating the central membrane with a laser and measuring the output voltage across one side of the device.

Although the device can provide voltages of several tens of mV, the power generation is relatively poor due to high contact resistance of the contacts between the legs, an issue which requires further development.

Doping	Concentration (cm^{-3})	Mobility (cm^2/Vs)	Resistivity (mohmcm)	Thermal conductivity at RT (W/mK)
p-type (Boron)	7.9E19	41	1.9	32
n-type (Phosphorus)	4.8E19	79	1.6	33

Table 2. Electrical and thermal properties of highly doped 40 nm thick p- and n-type Si membranes.

VTT also simulated Si coolers and generators which looks promising, for example the generated by one leg pair at room temperature can be of several microwatts, which can be increased by increasing the number of leg pairs.

WP5 – GeMn films for Device-like Structures

Optimised GeMn samples have been grown at CEA, who leads this workpackage) for which a thermal conductivity of 3 $W\text{-}m^{-1}\text{-}K^{-1}$ has been measured. This value is lower than Ge bulk by a factor 20. The ZT of GeMn has been determined to be between 0.1 and 0.5 at room temperature depending on doping level (p and n type).

The GeMn/Ge materials examined by EELS showed that manganese is present only inside the GeMn clusters since the Mn concentration in the germanium matrix Mn is below the detection limit of about 0.5%.

N-type doping and p-type doping on GeMn samples have been successfully achieved by implantation, which opens the possibility of GeMn based thermoelectric device. The process was checked against damage of the GeMn nanocrystals and found not to be harmful.

WP1 – TEG Specifications

The objectives of this workpackage were to identify potential thermoelectric applications and derive requirements for the performance of the modules and hence for the materials. This enabled the consortium to provide a frame of reference for the properties and characteristics to be sought for while developing and fabricating the materials selected. CIDETE led this WP and carried out a market analysis and a patent search. Initially, two applications were identified, namely, a cooler for a CMOS-integrated camera and a TEG suitable for integration in a concentrator-base photovoltaic cell. However, at the mid-term review, considering the results and material performance so far, the potential application was changed to a sensor, which would work with low voltages generated by the membrane-based TEG module.

The two possible applications selected in the first half of the project were changed at the request of the mid-term reviewers' report to sensor which could benefit from TE cooling.

WP6 – Lab-scale Device Module

In order to process adequately the electric power produced by a TE device an electronic circuit able to adapt the different electronic variables: current, tension and power is necessary.

When the energy to power the processor module is extremely low (ultra-low power) the main problem is to start the commutation system composed by the switches and capacitors. In MERGING we developed and improved over a series of prototypes a processor module, able to generate up to 5 V from an input of 7 mV. This power processor, tested on a commercial TE module, is able to power a board working as a temperature sensor. Low power applications include real time clock (100 nW), calculators and watches (1 uW), RFID tags (10 uW), remote sensing and control (100 uW), etc.

4.1.4 The potential impact

We have shown that membrane technology can generate power of a few 100s of microwatts at RT for a temperature difference of 100 K, using a single n-p pair in a 40 nm thick Si membrane. This translates into a maximum voltage of about 30 mV.

The composition of the consortium and the work plan ensured the feedback between the targeted materials and structures with the desired improved thermal properties and the performance in a TE module, mediated by a deeper understanding of heat transport, complete the loop science-technology. In particular, the TEG module which included a tailor-made power circuit to boost the low voltage generation was successfully tested on a lab-scale using a commercially available temperature sensor (sensitive to the heat generated by a human finger) and it generated electricity generation suitable for lighting up a visible LED. The circuit design was made with as close to the MERGING material parameters and performance, so that a straight replacement would be made once the TE modules became available. While the Si membrane based module was tested, as was a commercially available BiTe fabricated into a suspended membrane, the work on the MnGe membranes managed a promising doping level too close to the end of the project for a TE device to be fabricated. The technology development for a suspended membrane of MnGe is still a challenge.

The technological developments made in MERGING will impact energy harvesting and energy control in information and communication technologies, covering autonomous and embedded sensors, making use of the otherwise waste heat in a number of widely used devices, such as LEDs, Vertical cavity emitting lasers (VECSLs) and Quantum Cascade Lasers (QCLs) used mainly in the mid-infrared and known for being affected by thermal management issues. But perhaps one of the major fields to be impacted by a compact and light TEG is the Internet of Things.

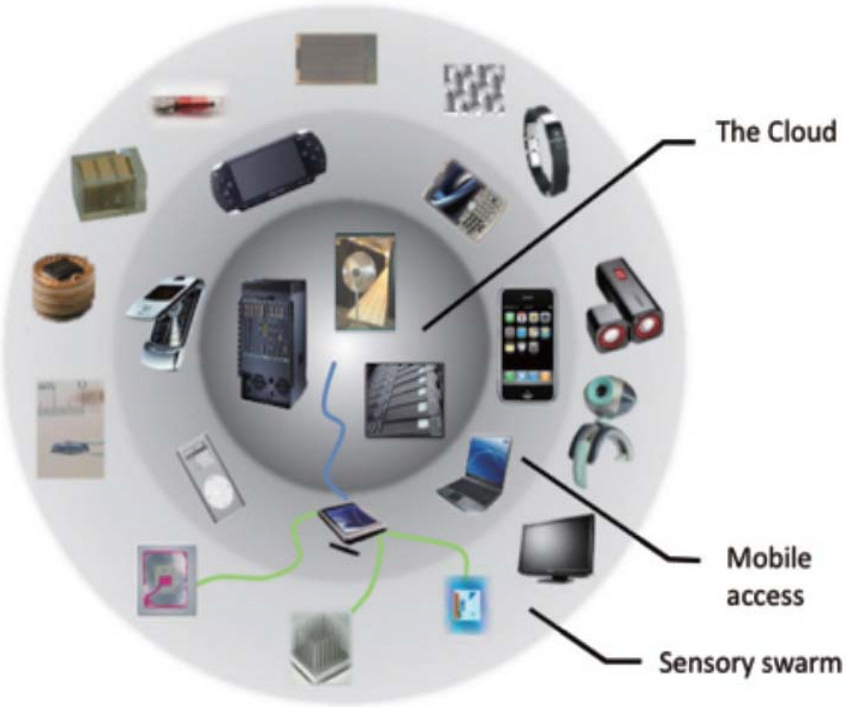


Figure 13. The picture shows the increasing range of mobile devices and sensors, which need energy for functioning. Thus, energy harvesting, low power (= or less than 10 uW) and energy efficiency constitute main challenges for autonomous systems. (from: J M Rabaey, 2011 Symp. VLSI Circuits Digest of Technical Papers).

We expect the potential impact in a wider scale will be felt in the societal challenges of Energy, Communications and Transport, in the first instance, and most probably health and environment, if the TE membrane technology can be incorporated in the design, processing and packaging of autonomous systems, which could be higher TRL-based project.

Main dissemination activities and exploitation of results

Publications:

During the length of the project, the consortium has published 19 peer-reviewed articles including one position paper on nanophononics. The obtained results were disseminated ensuring open-access content or, when not possible, a preprint version was deposited on arXiv.org and ResearchGate.net.

Furthermore, the dissemination was carried out by all the partners participating in international conferences, workshops, invited lectures and seminars. The results of the project were presented in over 90 oral presentations and poster sessions. Among these, over 40 were invited talks, seminars and lectures.

LIST OF REFEREED JOURNAL PUBLICATIONS:

The list of publications acknowledging MERGING is detailed in Template A1.

LIST OF CONFERENCE PROCEEDINGS:

1. Nanoimprint-assisted directed self-assembly of low-molecular weight block copolymers: a route for 3D and multilevel nanostructures, C. Simão, W. Khunsin, N. Kehagias, A. Francone, M. Zelsmann, M. A. Morris, and C. M. Sotomayor Torres, Micro- and Nanotechnology Sensors, Systems, and Applications VI, Proc. SPIE 9083, 90832S (2014).
2. Order and defectivity nanometrology by image processing and analysis of sub-20 nm BCPs features for lithographic applications, C. Simão, D. Tuchapsky, W. Khunsin, A. Amann, M. A. Morris, C. M. Sotomayor

Torres, Dimensional Optical Metrology and Inspection for Practical Applications III, Proc. SPIE 9110, 91100R (2014).
3. Sensitive 3-omega measurements on epitaxial thermoelectric thin films, Y. Q. Liu, D. Tainoff, M. Boukhari, J. Richard, A. Barski, P. Bayle-Guillemaud, E. Hadji and O. Bourgeois, IOP Conf. Ser.: Mater. Sci. Eng., 68, 012005 (2014).

Invited and contributed conference presentations:

Partners have also presented the results of their research in 90 international conference, invited talks, oral talks and poster presentations. The list is below:

LIST OF CONFERENCE PRESENTATIONS:

The list of conference presentations is detailed in Template A2.

4.1.5 Project public website and relevant contact details.

Project public website: www.merging.eu
Contact: Prof. Dr. C. M, Sotomayor Torres: clivia.sotomayor@icn2.cat

4.1.6 Project logo, diagrams or photographs illustrating and promoting the work of the project, the list of all beneficiaries with the corresponding contact names

The MERGING Consortium

	Participant organisation name	**Contact person and email**	**Country**
1	Catalan Institute of Nanotechnology (ICN)	Prof Dr Clivia M Sotomayor Torres clivia.sotomayor@icn2.cat	Spain
2	Commissariat à l'Énergie Atomique (CEA)	Dr Emmanuel Hadji emmanuel.hadji@cea.fr	France
3	Technical Research Centre of Finland (VTT)	Prof Dr Jouni Ahopelto jouni.ahopelto@vtt.fi	Finland
4	Centre National de la Recherche Scientifique (CNRS)	Prof Dr Olivier Bourgeois olivier.bourgeois@neel.cnrs.fr	France
5	*Max Planck* Gesellschaft (MPG)	Prof Dr Davide Donadio ddonadio@ucdavis.edu	Germany/ USA
6	Cidete Ingenieros (CIDETE)	Mr German Noriega gnoriega@cidete.com	Spain

4.2 Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

- Section A

  This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B

  This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

Section A (public)

This section includes two templates

- Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[3] (if available)	Is/Will open access[4] provided to this publication?
1	*Fabrication of phononic crystals on free-standing silicon membranes*	*M. Sledzinska*	*Microelec-tronic Enginee-ring*	*149, January 2016*	*Elseviewer*	*United States of America*	*2016*	*41-45*	*http://www.sciencedirect.com/science/article/pii/S0167931715300502*	*Yes*
2	*Thermal conductivity of silicon nitride membranes is not sensitive to stress*	*H. Ftouni*	*Physical Review B*	*92 (July 2015)*	*IOP Science*	*United States of America*	*2015*	*125439*	*http://arxiv.org/abs/1506.01838*	*Yes*
3	*Reconstructing phonon mean free path contributions to thermal conductivity using nanoscales membranes*	*J. Cuffe*	*Physical Review B*	*91 (24), June 2015*	*American Physical Society*	*United States of America*	*2015*	*P 245423*	*http://journals.aps.org/prb/abstract/10.1103/PhysRevB.91.245423*	*Yes*

[3] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[4] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

4	*Tuning Thermal Transport in Ultrathin Silicon Membranes by Surface Nanoscale Engineering*	*S. Neogi*	*ACS Nano*	*9 (4), April 2015*	*American Chemical Society*	*United States of America*	*2015*	*pp 3820–3828*	http://pubs.acs.org/doi/abs/10.1021/nn506792d	*Yes*
5	*Thermal transport in free-standing silicon membranes: influence of dimensional reduction and surface nanostructures*	*S. Neogi*	*The European Physical Journal B*	*88 (3), March 2015*	*Springer*	*Germany*	*2015*	*pp. 1-9*	http://link.springer.com/article/10.1140/epjb/e2015-50677-5	*Yes*
6	*Phonon dispersion in hypersonic two-dimensional phononic crystal membranes*	*B. Graczykowski*	*Physical Review B*	*91 (7), February 2015*	*American Physical Society*	*United States of America*	*2015*	*p. 075414*	http://journals.aps.org/prb/abstract/10.1103/PhysRevB.91.075414	*Yes*
7	*Sensitive 3-omega measurements on epitaxial thermoelectric thin films*	*Y.Q. Liu*	*Materials Science and Enginee-ring*	*68 (2014)*	*IOP Science*	*France*	*2014*	*012005*	http://iopscience.iop.org/article/10.1088/1757-899X/68/1/012005/pdf	*Yes*
8	*Formation of Titanium Nanostructures on Block Copolymer Templates with Varying Molecular Weights*	*M. Kreuzer*	*Macromolecules*	*47 (24), December 2014*	*American Chemical Society*	*United States of America*	*2014*	*pp. 8691–8699*	http://pubs.acs.org/doi/abs/10.1021/ma501605s	*No*
9	*Modification of Akhieser mechanism in Si nanomembranes and thermal conductivity dependence of the Q-factor of high frequency nanoresonators*	*E. Chávez-Ángel*	*Semiconductor Science and Technolo-gy*	*29 (12), November 2014*	*IOP Science*	*England*	*2014*	*p. 124010*	http://iopscience.iop.org/0268-1242/29/12/124010	*No*
10	*Heat transmission between a profiled nanowire and a thermal bath*	*C. Blanc*	*Applied Physics Letters*	*105 (4), July 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 043106.*	http://scitation.aip.org/content/aip/journal/apl/105/4/10.1063/1.4890963	*No*
11	*Nanoarchitecture Effects on Persistent Room Temperature Photoconductivity and Thermal Conductivity in Ceramic Semiconductors: Mesoporous, Yolk-Shell and Hollow ZnO Spheres*	*S. Dilger*	*Crystal Growth and Design*	*14 (9), August 2014*	*American Chemical Society*	*United States of America*	*2014*	*pp. 4593–4601*	http://pubs.acs.org/doi/abs/10.1021/cg500680g	*No*
12	*Acoustic phonon propagation in ultra-thin Si membranes under biaxial stress field*	*B. Graczykowski*	*New Journal of Physics*	*16 (7), July 2014*	*IOP Science*	*England*	*2014*	*p. 073024*	http://iopscience.iop.org/1367-2630/16/7/073024	*Yes*

13	*Tensile strain mapping in flat germanium membranes*	*S. D. Rhead*	*Applied Physics Letters*	*104 (17), May 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 172107*	http://scitation.aip.org/content/aip/journal/apl/104/17/10.1063/1.4874836	*No*
14	*High quality single crystal Ge nano-membranes for opto-electronic integrated circuitry*	*V. A. Shah*	*Journal of Applied Physics*	*115 (14), April 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 144307*	http://scitation.aip.org/content/aip/journal/jap/115/14/10.1063/1.4870807	*No*
15	*Hypersonic phonon propagation in one-dimensional surface phononic crystal*	*B. Graczykowski*	*Applied Physics Letters*	*104 (12), March 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 123108*	http://scitation.aip.org/content/aip/journal/apl/104/12/10.1063/1.4870045	*Yes*
16	*A novel contactless technique for thermal field mapping and thermal conductivity determination: Two-Laser Raman Thermometry*	*J. S. Reparaz*	*Review of Scientific Instruments*	*85 (3), March 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 034901*	http://scitation.aip.org/content/aip/journal/rsi/85/3/10.1063/1.4867166	*Yes*
17	*Reduction of the thermal conductivity in free-standing silicon nano-membranes investigated by non-invasive Raman thermometry*	*E. Chávez-Ángel*	*Applied Physics Letters Materials*	*2 (1), January 2014*	*American Institute of Physics*	*United States of America*	*2014*	*p. 012113*	http://scitation.aip.org/content/aip/journal/aplmater/2/1/10.1063/1.4861796	*Yes*
18	*Specific heat measurement of thin suspended SiN membrane from 8 K to 300 K using the 3ω-Völklein method*	*H. Ftouni*	*Review of Scientific Instruments*	*84 (9), September 2013*	*American Institute of Physics*	*United States of America*	*2013*	*p. 094902*	http://scitation.aip.org/content/aip/journal/rsi/84/9/10.1063/1.4821501	*No*
19	*Phonon heat conduction in corrugated silicon nanowires below the Casimir limit*	*C. Blanc*	*Applied Physics Letters*	*103 (4), July 2013*	*American Institute of Physics*	*United States of America*	*2013*	*p. 043109*	http://scitation.aip.org/content/aip/journal/apl/103/4/10.1063/1.4816590	*Yes*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[5]	Main leader	Title	Date/Period	Place	Type of audience[6]	Size of audience	Countries addressed
1	*Invited Talk*	*C. M. Sotomayor Torres*	*Upcoming*	*November 2016*	*MRS Fall Meeting (Boston, USA)*	*Scientifc Community*	*TBC*	*International*
2	*Invited Talk*	*C. M. Sotomayor Torres*	*Upcoming: Thermal transport in 2D membranes and phononic crystals*	*30 October 2016 – 11 November 2016*	*Workshop on Thermal and Electronic Transport in Nanostructures (Natal – Brazil)*	*Scientifc Community*	*TBC*	*International*
3	*Plenary Talk*	*C. M. Sotomayor Torres*	*Upcoming: Phononic thermal conductivity in ultra-thin membranes and 2D phononic crystals*	*May 2016*	*Nano2016 (Buenos Aires, Argentina)*	*Scientifc Community*	*TBC*	*International*
4	*Invited Talk*	*C. M. Sotomayor Torres*	*Upcoming: Heat propagation in free-standing SOI membranes: a model system*	*10-15 April 2016*	*W Hereus Workshop on Heat Transfer and Heat Conduction on the Nano scale (Bad Honnef, Germany)*	*Scientifc Community*	*TBC*	*International*
5	*Invited Talk*	*C. M. Sotomayor Torres*	*Upcoming: Phononic and electronic thermal conductivity in the Nano scale*	*4-6 April 2016*	*W Hereus Workshop on Heat Transfer and Heat*	*Scientifc Community*	*TBC*	*International*

[5] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[6] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

					Conduction on the Nano scale (Bad Honnef, Germany)			
6	*Invited Talk*	*C. M. Sotomayor Torres*	*Thermal transport in 2D membranes and phononic crystals*	*February 2016*	*30th International winterschool on the Electronic Properties of Novel Materials IWEPNM 2016 (Kirchberg, Austria)*	*Scientifc Community*	*50*	*International*
7	*Invited Talk*	*D. Donadio*	*Thermoelectric properties of silicon membranes and molecular junction*	*January 2016*	*ICOT2016 (Tokyo, Japan)*	*Scientifc Community*	*40*	*International*
8	*Talk, Conference*	*O. Bourgeois*	*Significant reduction of thermal conductivity in a nanostructured semiconductor single crystal*	*November 2015*	*GDR Thermoelectricity (Caen, France)*	*Scientifc Community*	*50*	*International*
9	*Invited talk*	*C. M. Sotomayor Torres*	*Thermal transport in free-standing silicon membranes: confinement, intrinsic and extrinsic contributions*	*4 December 2015*	*25th SLAFES (Puerto Varas, Chile)*	*Scientifc Community*	*50*	*International*
10	*Invited talk*	*C. M. Sotomayor Torres*	*Thermal transport in free-standing silicon membranes: confinement, intrinsic and extrinsic contributions*	*30 November 2015*	*MRS Fall Meeting 2015 (Boston, USA)*	*Scientific Community*	*50*	*International*
11	*Invited talk*	*C. M. Sotomayor Torres*	*Understanding thermal conductivity in ultra-thin SOI*	*21 October 2015*	*EU-Korea Workshop on Nanoelectronics (Lisbon, Portugal)*	*Scientific Community*	*50*	*International*
12	*Talk, Conference*	*D. Tainoff*	*Significant reduction of thermal conductivity in a nanostructured semiconductor single crystal*	*October 2015*	*Workshop Hot Nanostructures (Mainz, Germany)*	*Scientifc Community*	*100*	*International*
13	*Keynote talk*	*D. Donadio*	*Ultra-thin silicon membranes and silicon nanowires as nanophonics and thermoelectric devices*	*September 2015*	*IWCE Workshop (Purdue, USA)*	*Scientifc Community*	*50*	*International*
14	*Invited talk*	*S. Xiong*	*Combined phonon resonance and scattering effects enable thermal conductivity below the amorphous limit*	*September 2015*	*EMRS Fall Meeting (Warsaw, Poland)*	*Scientific Community*	*60*	*International*
15	*Talk, Conference*	*M. Boukhari*	*Germanium manganese based nanostructures for thermoelectric*	*September 2015*	*EMRS Fall Meeting*	*Scientific Community*	*300*	*International*

			applications		*(Warsaw, Poland)*			
16	*Poster presenta-tion*	*S. Xiong*	*Thermal conductivity reduction in Si membrane with alloying and surface engineering*	*September 2015*	*Hot Nanostructures CECAM Workshop (Mainz, Germany)*	*Scientific Community*	*50*	*International*
17	*Talk, Conference*	*B. Graczykowski*	*Silicon nanomembrane-based phononics*	*12-17 July 2015*	*Phonons 2015 (Nottingham, UK)*	*Scientific Community*	*70*	*International*
18	*Talk, Conference*	*F. Alzina*	*Silicon nanomembrane-based phononics*	*12-17 July 2015*	*Phonons 2015 (Nottingham, UK)*	*Scientific Community*	*70*	*International*
19	*Talk, Conference*	*C. M. Sotomayor Torres*	*Thermal transport in free-standing silicon membranes*	*7-10 July 2015*	*CECAM-FR-IDF workshop (Paris, France)*	*Scientific Community*	*80*	*International*
20	*Talk, Conference*	*Y. Liu*	*Significant reduction of thermal conductivity in a nanostructured semiconductor single crystal*	*July 2015*	*International Conference on Phonon Scattering in Condensed Matter (Nottingham, UK)*	*Scientific Community*	*300*	*International*
21	*Talk, Conference*	*Ad. Tavakoli*	*Specific heat in 2D suspended SiN membranes at low temperature*	*July 2015*	*International Conference on Phonon Scattering in Condensed Matter (Nottingham, UK)*	*Scientific Community*	*300*	*International*
22	*Talk, Conference*	*M. Boukhari*	*Germanium manganese based nanostructures for thermoelectric applications*	*July 2015*	*ICT-ECT (Dresden, Germany)*	*Scientific Community*	*100*	*International*
23	*Invited talk*	*C. M. Sotomayor Torres*	*Thermal transport in free-standing silicon membranes*	*June 2015*	*CECAM Workshop on Nanostructures for Thermoelectrics (Paris, France)*	*Scientific Community*	*50*	*International*
24	*Invited talk*	*D. Donadio*	*How surfaces dictate thermal transport in low-dimensional semiconductors*	*June 2015*	*Vibrations at surfaces VAS15 (San Sebastián,*	*Scientific Community*	*50*	*International*

					Spain)			
25	Invited talk	D. Donadio	Machine learning approaches to simulate nanoscale heat transport	June 2015	PASC15 Conference (ETH Zurich, Switzerland)	Scientific Community	50	International
26	Invited talk	D. Selli	Improved thermoelectric features in low dimensional silicon-based devices	June 2015	CECAM Workshop on "Advanced thermoelectrics at nanoscale: from materials to devices) (Paris, France)	Scientific Community	50	International
27	Invited talk	S. Xiong	Combined phonon resonance and scattering effects enable thermal conductivity below the amorphous limit	June 2015	12th ETSF Young Researchers Mtg (Paris, France)	Scientific Community	50	International
28	Talk, Conference	Ad. Tavakoli	Specific heat in 2D suspended SiN membranes at low temperature	June 2015	Intl. Conference of Phononics 2015 (Paris, France)	Scientific Community	300	International
29	Talk, Conference	Y. Liu	Significant Reduction of Thermal Conductivity in a Nanostructured Semiconductor Single Crystal	June 2015	Intl. Conference of Phononics 2015 (Paris, France)	Scientific Community	300	International
30	Talk, Conference	B. Graczykowski	Brillouin Spectroscopy of Silicon-based Phononic Crystals	31 May-06 June 2015	Phononics 2015 (Paris, France)	Scientific Community	50	International
31	Talk, Conference	B. Graczykowski	Stress-and phononic induced changes in GHz phonon propagation in thin Si membranes	10-14 May 2015	2015 International Congress of Ultrasonics (Metz, France)	Scientific Community	50	International
32	Invited seminar	S. Neogi	Tuning thermal transport in ultrathin silicon membranes by surface nanoscale engineering	May 2015	IBM Watson (New York, USA)	Scientific Community	50	International
33	Talk, Conference	J.S. Reparaz	A novel approach to determine the spectral bandwidth of thermal phonons and mean-free path in silicon free-standing membranes	6-10 April 2015	MRS Spring meeting 2015 (San Francisco, USA)	Scientific Community	60	International
34	Invited seminar	D. Donadio	Nanophonics: controlling heat at the nanoscale	April 2015	Department of Electrical	Scientific Community	50	International

					Engineering, Stanford University (California, USA)			
35	*Invited talk*	*D. Donadio*	*Phonons and heat transport in two-dimensional systems*	*April 2015*	*MRS Spring Meeting (San Francisco, USA)*	*Scientific Community*	*50*	*International*
36	*Invited talk*	*D. Donadio*	*Hierarchical nanostructured materials for phonon control and thermoelectric applications*	*March 2015*	*Imaginenano (Bilbao, Spain)*	*Scientific Community*	*50*	*International*
37	*Invited Talk, Conference*	*J.S. Reparaz*	*Thermal transport in nanostructured materials: Can we control thermal phonons?*	*16-17 February 2015*	*Son et Lumière Workshop (Les Houces, France)*	*Scientific Community*	*70*	*International*
38	*Talk, Conference*	*O. Bourgeois*	*Thermal instrumentation and measurements for micro and nano systems using electrical and optical methods*	*December 2014*	*Lecture at Quantiheat School (Frejus, France)*	*Scientific Community*	*200*	*International*
39	*Talk, Conference*	*C. M. Sotomayor Torres*	*Modification of the Akhieser mechanism in Si nanoresonators*	*15-17 October 2014*	*Eurotherm 103, Nano scale and Microscale Heat Transfer IV, (Lyon France)*	*Scientific Community*	*100*	*International*
40	*Invited Talk, Workshop*	*C. M. Sotomayor Torres*	*Phonons in free-standing Si membranes*	*05-12 October 2014*	*International School on Quantum Electronics, Third Mediterranean International Workshop on Photoacoustic & Photothermal phenomena, (Erice Italy)*	*Scientific Community*	*70*	*International*
41	*Talk, Conference*	*O. Bourgeois*	*Nanophonics at low temperature: manipulating heat at the nanoscale*	*October 2014*	*Workshop on Nanoscale Heat Transfer (Konstanz, Germany)*	*Scientific Community*	*100*	*International*

42	*Invited Talk, Workshop*	*F. Alzina*	*Reduced Thermal conductivity in Nanostructures and the Intrinsic Limit of the Q-factor in Nano-Mechanical Resonators*	*01-04 September 2014*	*EUPHONON workshop, (Le Mans France)*	*Scientific Community*	*50*	*International*
43	*Invited Talk, Workshop*	*J. S. Reparaz*	*Influence of size and roughness on the thermal conductivity of free-standing Si membranes investigated using 2-laser Raman thermometry*	*01-04 September 2014*	*EUPHONON workshop, (Le Mans France)*	*Scientific Community*	*50*	*International*
44	*Invited Talk, Workshop*	*S. Neogi and D. Donadio*	*Phononic thermal transport in nanostructured ultra-thin silicon membranes*	*01-04 September 2014*	*EUPHONON workshop, (Le Mans France)*	*Scientific Community*	*60*	*International*
45	*Invited Talk, Workshop*	*O. Bourgeois*	*Thermal properties of suspended SiN membranes under the presence of stress*	*01-04 September 2014*	*EUPHONON workshop, (Le Mans France)*	*Scientific Community*	*50*	*International*
46	*Invited Talk, Conference*	*O. Bourgeois*	*Nanophononics: from low temperature to room temperature phonon physics*	*24-29 August 2014*	*Condensed Matter Division 25, (Paris France)*	*Scientific Community*	*50*	*International*
47	*Invited Talk, Workshop*	*D. Donadio*	*Phonon manipulation by nanostructuring for energy harvesting and thermal management*	*20-22 August 2014*	*Computational Science Workshop, (Tsukuba Japan)*	*Scientific Community*	*40*	*International*
48	*Talk, Conference*	*M. Sledzinska*	*Large area hierarchichal micro/nano structures for enhanced self-cleaning applications*	*8-11 July 2014*	*11th International Conference on Nanosciences & Nanotechnologie s (NN14)*	*Scientific Community*	*50*	*International*
49	*Invited Talk, Conference*	*D. Donadio*	*Manipulation of heat transport in two-dimensional nanostructures*	*26-30 May 2014*	*E-MRS spring 2014, (Lille France)*	*Scientific Community*	*50*	*International*
50	*Invited Talk, Conference*	*Yanqing Liu*	*Thermal properties of an « Electron crystal – phonon glass » thin film*	*26-30 May 2014*	*E-MRS spring 2014, (Lille France)*	*Scientific Community*	*50*	*International*
51	*Talk, Conference*	*J. S. Reparaz*	*Thermal conductivity and thermal field distribution determination in free-standing Si and Ge membranes*	*26-30 May 2014*	*E-MRS spring 2014, (Lille France)*	*Scientific Community*	*70*	*International*
52	*Poster*	*M. R. Wagner*	*Heat propagation and thermal phonon dynamics in group IV nanostructures*	*26-30 May 2014*	*E-MRS spring 2014, (Lille France)*	*Scientific Community*	*120*	*International*
53	*Poster*	*E. Chávez-Ángel*	*Modelling of the phonon attenuation in Si-based nanostructures*	*26-30 May 2014*	*E-MRS spring 2014, (Lille*	*Scientific Community*	*120*	*International*

					France)			
54	Talk, Conference	J. S. Reparaz	A novel high resolution contactless technique for thermal field mapping and thermal conductivity determination: Two-Laser Raman Thermometry	26-30 May 2014	E-MRS spring 2014 (Lille France)	Scientific Community	80	International
55	Talk, Conference	E. Chávez-Ángel	Theoretical thermal rectification in Si and Ge thin films	26-30 May 2014	E-MRS spring 2014 (Lille France)	Scientific Community	50	International
56	Invited Seminar	C. M. Sotomayor Torres	Thermal transport in suspended Si membranes	15 May 2014	Linkoeping University, Dept. of Physics, Chemistry and Biology (Linkoeping Sweden)	Scientific Community	50	International
57	Invited Talk, Conference	D. Donadio	Simulating heat transport: from large scale molecular dynamics to first-principles calculations	31-04 April 2014	Non-equilibrium Phenomena at the Nano-scale session at the DPG Spring Meeting, (Dresden Germany)	Scientific Community	50	International
58	Talk, Conference	B. Graczykowski	One-dimensional surface phononic crystals	11-14 March 2014	NanoSpain 2014, (Madrid Spain)	Scientific Community	60	International
59	Talk, Conference	J. S. Reparaz	A novel contactless technique for thermal field mapping and thermal conductivity determination: Two-Laser Raman Thermometry	11-14 March 2014	NanoSpain 2014, (Madrid Spain)	Scientific Community	60	International
60	Poster	M. R. Wagner	Acoustic phonon dynamics in free standing group IV semiconductor membranes studied by ultra-fast pump & probe spectroscopy	11-14 March 2014	NanoSpain 2014, (Madrid Spain)	Scientific Community	100	International
61	Poster	E. Chávez-Ángel	Theoretical thermal rectification in Si and Ge thin films	11-14 March 2014	NanoSpain 2014, (Madrid Spain)	Scientific Community	100	International
62	Invited Talk, Conference	O. Bourgeois	Phonons and thermal physics at the micro and nanoscale	03-07 March 2014	March Meeting of the American Physical Society, (Denver United States)	Scientific Community	40	International

63	*Invited Talk, Conference*	*D. Donadio*	*Heat transport in nanostructures: discrepancies between equilibrium and non-equilibrium simulations*	*18-20 December 2013*	*“Five pieces and a do in computational physics”, (Rome Italy)*	*Scientific Community*	*40*	*International*
64	*Invited Talk, Conference*	*C. M. Sotomayor Torres*	*Phonons in Silicon Free-Standing Membranes: From Slow Phonons to Engineering Thermal Conductivity*	*02-06 December 2013*	*MRS Fall meeting 2013 (Boston United States)*	*Scientific Community*	*120*	*International*
65	*Talk, Conference*	*J. Cuffee*	*Phonon mean free path reconstruction from thermal conductivity measurements of nanoscale silicon membranes*	*1-6 December 2013*	*MRS fall meeting 2013 (Boston, USA)*	*Scientific Community*	*60*	*International*
66	*Talk, Conference*	*M. R. Wagner*	*Impact of boundary scattering on nanoscale thermal transport properties in ultra-thin Si-based nanostructures*	*15-21 November 2013*	*ASME 2013 International Mechanical Engineering, (San Diego United States)*	*Scientific Community*	*40*	*International*
67	*Talk, Conference*	*J. S. Reparaz*	*Raman thermometry as contactless method for thermal conductivity determination: The case of thermal conductivity reduction in Si and Ge*	*15-21 November 2013*	*ASME 2013 International Mechanical Engineering, (San Diego United States)*	*Scientific Community*	*40*	*International*
68	*Talk, Conference*	*J. Cuffe*	*Thermal Conductivity of Nanoscale Silicon Membranes*	*15-21 November 2013*	*ASME 2013 International Mechanical Engineering, (San Diego United States)*	*Scientific Community*	*80*	*International*
69	*Talk, Conference*	*E. Chávez-Ángel*	*Thermal Conductivity of nm-scale Membranes by Raman Thermometry*	*05-08 November 2013*	*26th International Microprocesses and Nanotechnology Conference, (Sapporo Japan)*	*Scientific Community*	*80*	*International*
70	*Oral Presenta-tion*	*C. M. Sotomayor Torres*	*Thermal Conductivity of nm-scale Membranes by Raman Thermometry*	*05-08 November 2013*	*26th International Microprocesses and Nanotechnology Conference, (Sapporo Japan)*	*Scientific Community*	*80*	*International*

71	*Oral Presenta-tion*	*C. M. Sotomayor Torres*	*Effect of phonon confinement on the dispersion relation and heat capacity in nanoscale Si membranes*	*12-15 November 2013*	*ASME IMECE (Houston, USA)*	*Scientific Community*	*50*	*International*
72	*Invited Lecture, Workshop*	*D. Donadio*	*Thermal transport in one-, two- and three-dimensional carbon nanostructures from atomistic simulations*	*21-25 October 2013*	*Workshop on Hot Nanostructures, (Leiden Netherlands)*	*Scientific Community*	*50*	*International*
73	*Talk, Conference*	*M. R. Wagner*	*Nanoscale thermal transport and phonon dynamics in ultra-thin Si based nanostructures*	*25-28 September 2013*	*Therminic 2013, (Berlin Germany)*	*Scientific Community*	*40*	*International*
74	*Talk, Conference*	*J. S. Reparaz*	*Thermal conductivity reduction in Si and Ge free-standing membranes investigated using Raman thermometry*	*25-28 September 2013*	*Therminic 2013, (Berlin Germany)*	*Scientific Community*	*40*	*International*
75	*Talk, Conference*	*B. Graczykowski*	*Hypersonic phonon propagation in prestressed ultra-thin Si membranes*	*16-20 September 2013*	*E-MRS fall 2013, (Warsaw Poland)*	*Scientific Community*	*60*	*International*
76	*Poster*	*M.Sledzinska*	*Tuning of the Surface Acoustic Waves in Silicon Phononic Crystals*	*16-20 September 2013*	*E-MRS fall 2013, (Warsaw Poland)*	*Scientific Community*	*90*	*International*
77	*Invited Talk*	*C. M. Sotomayor Torres*	*Thermal conductivity in Free-standing Si and Ge Membranes*	*02-04 September 2013*	*First International Conference on Phononics and Thermal Energy Science (Shanghai, China)*	*Scientific Community*	*150*	*International*
78	*Invited Lecture, Workshop*	*J. Ahopelto*	*Free-standing silicon membranes: a tool to investigate thermal properties of low-dimensional systems*	*19-23 August 2013*	*CECAM workshop on Nanophononics, (Bremen Germany)*	*Scientific Community*	*70*	*International*
79	*Invited Lecture, Workshop*	*C. M. Sotomayor Torres*	*Confined phonons and thermal conductivity in Si ultra-thin membranes*	*19-23 August 2013*	*CECAM workshop on Nanophononics, (Bremen Germany)*	*Scientific Community*	*70*	*International*
80	*Talk, Conference*	*B. Graczykowski*	*Acoustic phonons propagation in ultrathin Si membranes under biaxial stress*	*10-12 July 2013*	*Quantitative Micro and Nano Thermal Imaging and Analysis*	*Scientific Community*	*50*	*International*

					2013, (Reims France)			
81	*Invited Talk, Workshop*	*D. Donadio*	*Modelling of thermal transport by Molecular Dynamics*	*25-29 June 2013*	*TSRC workshop on Thermal Transport at the Nanoscale, (Telluride United States)*	*Scientific Community*	*50*	*International*
82	*Plenary Talk, Conference*	*C. M. Sotomayor Torres*	*Acoustic Phonons in Silicon Free-Standing Membranes: From Slow Phonons to Engineering Thermal Conductivity*	*02-07 June 2013*	*Phononics 2013, (Sharm El-Sheikh Egypt)*	*Scientific Community*	*120*	*International*
83	*Invited Talk, Conference*	*C. Blanc*	*Phonon Thermal Transport in Periodically Structured Nanosystems*	*02-07 June 2013*	*Phononics 2013, (Sharm El-Sheikh Egypt)*	*Scientific Community*	*120*	*International*
84	*Plenary Talk, Conference*	*L. F. C. Pereira , and D. Donadio*	*Phonon Transport in Graphene: Effects of Strain and of Finite Temperature Gradients*	*02-07 June 2013*	*Phononics 2013, (Sharm El-Sheikh Egypt)*	*Scientific Community*	*120*	*International*
85	*Poster*	*C. M. Sotomayor Torres*	*Si and Ge Membranes Investigated through Raman Thermometry: The Role of Phonon Boundary Scattering and Phonon Confinement in 2D Systems*	*02-07 June 2013*	*Phononics 2013, (Sharm El-Sheikh Egypt)*	*Scientific Community*	*120*	*International*
86	*Talk, Conference*	*J. S. Reparaz*	*Determination of the thermal conductivity of Si and Ge thin membranes through Raman thermometry*	*27-31 May 2013*	*E-MRS spring 2013, (Strasbourg France)*	*Scientific Community*	*60*	*International*
87	*Talk, Conference*	*M. R. Wagner*	*Acoustic phonon dynamics in free-standing silicon and germanium membranes*	*27-31 May 2013*	*E-MRS spring 2013, (Strasbourg, France)*	*Scientific Community*	*60*	*International*
88	*Invited Seminar*	*C. M. Sotomayor Torres*	*Thermal Conductivity in Ultra-thin Si Membranes*	*24 May 2013*	*Tampere Technical University (Finland)*	*Scientific Community*	*50*	*International*
89	*Invited Lecture*	*M. Prunnila*	*Acoustic phonon tunneling and heat transport due to evanescent electric fields*	*12-17 May 2013*	*Nanoscale Radiative Heat Transfer, Physics School Les Houches, (France)*	*Scientific Community*	*50*	*International*

90	*Invited Talk, Conference*	*E. Chávez-Ángel*	*Phonon Engineering for Heat Transport Control*	*23 - 26 April 2013*	*Imaginano 2013, (Bilbao Spain)*	*Scientific Community*	*80*	*International*
91	*Talk, Conference*	*S. Bhansali*	*Metal-oxide thin films as high efficiency thermoelectric materials*	*23 - 26 April 2013*	*Imaginano 2013, (Bilbao Spain)*	*Scientific Community*	*40*	*International*
92	*Talk, Conference*	*E. Chávez-Ángel*	*Thermal properties of silicon ultra-thin membranes: A theoretical and experimental approach*	*23 - 26 April 2013*	*Imaginano 2013, (Bilbao Spain)*	*Scientific Community*	*60*	*International*
93	*Invited Talk, Conference*	*J. Ahopelto*	*Ultra-Thin Free-Standing Silicon Membranes for Investigation of Thermal properties of Low-Dimensional Systems*	*23 - 26 April 2013*	*Imaginano 2013, (Bilbao Spain)*	*Scientific Community*	*60*	*International*
94	*Invited Talk*	*C. M. Sotomayor Torres*	*Phonon engineering for heat transport control*	*23 - 26 April 2013*	*Imaginano 2013, (Bilbao Spain)*	*Scientific Community*	*60*	*International*
95	*Invited Talk, Conference*	*E. Chávez-Ángel*	*Thermal Conductivity in Ultra-thin Si Membranes: Phonon Dispersion Relation and Lifetime Contributions*	*01 - 05 April 2013*	*MRS Spring meeting 2013, (San Francisco United States)*	*Scientific Community*	*50*	*International*
96	*Talk, Conference*	*J. S. Reparaz*	*Influence of Low Dimensionality on the Thermal Properties of Si, Ge, and SiNx Thin Membranes by Means of Optical and Electrical Techniques*	*01 - 05 April 2013*	*MRS Spring meeting 2013, (San Francisco United States)*	*Scientific Community*	*50*	*International*
97	*Poster*	*E. Chávez-Ángel*	*Modelling of Thermal Properties in Silicon Nanostructures*	*01 - 05 April 2013*	*MRS Spring meeting 2013, (San Francisco United States)*	*Scientific Community*	*100*	*International*
98	*Invited Talk*	*C. M. Sotomayor Torres*	*Thermal conductivity in ultra-thin Si membranes*	*01 - 05 April 2013*	*MRS Spring meeting 2013, (San Francisco United States)*	*Scientific Community*	*50*	*International*
99	*Invited Seminar*	*C. M. Sotomayor Torres*	*Thermal conductivity in ultra-thin Si membranes*	*25 February 2013*	*ICT, KTH (Kista, Sweden)*	*Scientific Community*	*50*	*International*

Section B (Confidential[7] or public: confidential information to be marked clearly)

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[8]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	Yes	01/02/2016	B14859	Innovative thermoelectric module operating as a thermopile	O. Bourgeois, D. Tainoff, D. Bourgault
Patent	Yes	2017	N/A	Thermoelectric device	A. Shchepetov, A. Timofeev, K. Grigoras, M. Prunnila, J. Ahopelto

[7] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[8] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground[9]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[10]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Patent	New thermoelectric module for energy harvesting	Yes	2016	Energy recovery chip	i) Energy recovery ii) Infra-red detector	2017-2018	Device patented in 2016	CNRS O. Bourgeois D. Tainoff D. Bourgault
General advancement of knowledge	Optimized GeMn-based material grown for thermoelectric applications	No	N/A	Materials development	i) Energy recovery ii) Cooling applications	2016 onwards	N/A	CEA
Fabrication process	Semiemperical atomistic code to compute ZT	Yes	N/A	Future collaboration in projects	Microelectronics, ICT, sensors	2017	Patent application	VTT
Atomistic thermoelectric simulation package	Surface oxidation to tune thermal conductivity	No	N/A	Service: installation and use of software	Electronics, energy	2017	The software will be released open source under GPL license	Davide Donadio, Daniele Selli
Procedure	Surface oxidation to tune thermal conductivity	No	No	Know how: design rule to improve TE performance	Energy, cooling, sensing	2017	This know is published	Davide Donadio, Sanghamitra Neogi, VTT, ICN2
Product	Electronic control for low power generators	Yes	N/A	Ultra-low power converter	Electronics, energy	2017	Application on existing products	CIDETE
General advancement of knowledge	Sub-um scale thermal conductivity measurements and 2-dimensional thermal maps	No	N/A	Future research projects and services to external users	i) Research in thermal materials, ii) Cooling of solids iii) Phononics	2016	No	ICN

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[10] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[9]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[10]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
					iv) Couple phonon systems to other excitations in solids v) Teaching and training			

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

Exploitable Foreground: Commercial exploitation of R&D results
Protection tool: Patent **Exploitation tool:** Product
Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: within two years **Sector of application:** Thermoelectrics **Possible customers:** Internet of things **Competitors:** Micropelt
Researchers involved: O. Burgeois, D. Tainoff **Maturity (TRL):** TRL3

Exploitable Foreground: Optimized GeMn-based material grown for thermoelectric applications
Protection tool: Know how Exploitation tool: Technology transfer about the growth of GeMn material
Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: 3/5 years Sector of application: Thermoelectric devices and modules, energy harvesting and thermal management in IOT applications Possible customers: Competitors:
Researchers involved: André Barski, Pascale Bayle-Guillemaud, Eric Delamadeleine, Thomas Charvolin, Emmanuel Hadji Maturity (TRL): TRL1-TRL2

Exploitable Foreground: Fabrication process
Protection tool: Know how Exploitation tool: Future collaboration in research projects
Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: N/A Sector of application: Microelectronics, phononics, thermoelectrics Possible customers: N/A Competitors: N/A
Researchers involved: A. Shchepetov, A. Varpula, A. Timofeev, M. Prunnila, J. Ahopelto Maturity (TRL): TRL4

Exploitable Foreground: Software to compute thermal and electronic transport in thermoelectric nanodevices
Protection tool: Software **Exploitation tool:** Service: providing assistance in the setup and use of the software
Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: 2 years **Sector of application:** Modelling of nanoscale electronic and thermoelectric devices **Possible customers:** Academics, developers of nanoelectronic components, sensors or thermoelectric devices **Competitors:** Quantumwise (atomistix toolkit)
Researchers involved: Davide Donadio, Daniele Selli **Maturity (TRL):** TRL1

Exploitable Foreground: Software to compute thermal and electronic transport in thermoelectric nanodevices
Protection tool: Know how **Exploitation tool:** Identification of design rules to control thermal conductivity by chemical surface treatment.
Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: 3 years **Sector of application:** Fabrication of thermoelectric nanodevices and components for nanoelectronic devices. **Possible customers:** Developers of nanoelectronic components, sensors or thermoelectric devices. **Competitors:** IEMN Lille
Researchers involved: Davide Donadio, Sanghamitra Neogi, VTT, ICN **Maturity (TRL):** TRL1

Exploitable Foreground: Electronic processor module for low power generator

Protection tool: Know how

Exploitation tool: Product

Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: 2017

Sector of application: Thermoelectrics, microelectronics

Possible customers: Developers of electronic and thermoelectric devices

Competitors: N/A

Researchers involved: G. Noriega

Maturity (TRL): TRL4

Exploitable Foreground: Raman scattering as a thermometry technique with sub-um resolution for 2D materials

Protection tool: Know how

Exploitation tool: Service and collaboration in future research with other materials and or structures applied also to industrially-relevant research as in thermal management

Commercial impact: framework for creating economic, social and/ or other forms of value. Timetable for commercial application: 2016

Sector of application: Phononics, thermoelectrics, materials, optoelectronics, nanoelectronics, IoT, autonomous systems and novel state variable. Data may also be useful for software developments of device simulations

Possible customers: Other researchers/research institutions, companies.

Competitors: anybody with expertise in advanced Raman scattering

Researchers involved: E Chavez-Angel, J S Reparaz, F Alzina, B Grazcykowski and C M Sotomayor Torres

Maturity (TRL): TRL2

4.3 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	309159
Title of Project:	Membrane-based phonon engineering for energy
Name and Title of Coordinator:	Prof Dr Clivia M Sotomayor Torres

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	*0Yes XNo*
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	

• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	0
Work package leaders	1	6
Experienced researchers (i.e. PhD holders)	4	16
PhD Students	2	3
Other	2	1

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	7
Of which, indicate the number of men:	3

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ X	Yes No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○

X Other: Encourage good practice at recruitment

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify: Put forward two PhD students for prizes at conferences

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

○ Main discipline[11]: 1.2

○ Associated discipline[11]: 2.2 | ○ Associated discipline[11]: 2.3

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ X	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No
○ Yes- in determining what research should be performed
○ Yes - in implementing the research
○ Yes, in communicating /disseminating / using the results of the project

[11] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**19**
To how many of these is open access[12] provided?	**12**
How many of these are published in open access journals?	**5**
How many of these are published in open repositories?	**7**
To how many of these is open access not provided?	**7**
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[13]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**2**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	

17. How many spin-off companies were created / are planned as a direct result of the project?	**0**
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	X	In small & medium-sized enterprises
X	Safeguard employment, or	X	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* **28**
Difficult to estimate / not possible to quantify	❑

[12] Open Access is defined as free of charge access for anyone via Internet.
[13] For instance: classification for security project.

I	Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes   X No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes   X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

2. FINAL REPORT ON THE DISTRIBUTION OF THE EUROPEAN UNION FINANCIAL CONTRIBUTION

This report shall be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.

Report on the distribution of the European Union financial contribution between beneficiaries

Name of beneficiary	Final amount of EU contribution per beneficiary in Euros
1. ICN	*845,582.48 €*
2. CEA	*729,587.71 €*
3. VTT	*639,579.12 €*
4. CNRS	*999,779.78 €*
5. MPG	*567,947.79 €*
6. CIDETE	*374,328.42 €*
Total	***4,156,805.01€***