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# PROJECT FINAL REPORT

**Grant Agreement number: 266600**

**Project acronym: NAPEP**

**Project title:** Nanotechnology platform for electronics and photonics

**Funding Scheme: Coordination and support action**

**Period covered: from 01 November 2010 to 30 December 2013**

**Name of the scientific representative of the project's co-ordinator[1], Title and Organisation:**

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**Project website**Ошибка! Закладка не определена. **address: www.napep.net**

[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:

**Executive summary**

Being the very first European research project coordinated by Azerbaijan, the primary goal of NAPEP was to integrate azeri researchers in general, and the staff of the Baku State University (BSU) in particular into the FP7 workflow of the European Union. This was achieved by closely following the workplan and organizing numerous technical meetings, seminars, training and brokerage events attended by all participant institutions as well as invited external experts and potential collaboration partners. Scientifically, the following method was found to deliver the best results:

1) Scientific projects related to the main theme of the NAPEP project were pursued at the partner institutes. The Finnish and the Hungarian partners have paid extra attention to integrate azeri participants into these projects. The integration was realized by various means, e.g. joint experiments, exchange of young researchers, discussion by experienced researchers etc.

2) The Nanotechnology Center of the Baku State Univesity was able to use the gathered experience in planning and carrying out research projects of its own.

**Project context and objectives**

The NAPEP project focuses on creating a nanotechnology platform at Baku State University through cooperation with nanotechnology centers in EU countries which is important for the development of research in the area of nanoelectronics and photonics in the collaborating countries. The project addresses the increasing cooperation capacity between NanoCenter Baku State University and EU research centers in the area of nanotechnology. The primary objective of this project is to create a nanotechnology research platform in the area of nanomaterials for electronics and photonics through collaboration of organizations from EU countries and Azerbaijan, mobilizing the regional scientific potential.

The general project goals are: Definition of the most promising fields of collaboration in area Nanoscience and nanotechnology research among the Azerbaijan and with the EU; Increase the number of highly qualified Azerbaijani scientists (by training research groups, by participation of young researchers on NAPEP Workshops); Strengthen the complex research and development infrastructure comprised of universities, technology centres, research networks, laboratories and libraries; Coordinate the actions of nanotechnology research groups, the scientific community and the private sector in Azerbaijan. In order to achieve these goals was organized meetings for discussing plans of joint Research with EU collaborators, train young persons in efficient networking, carry out seminars and disseminated results obtained during the implementation of project. The basic output of the project will be the development of the strategy of integrating the “Nanocenter“ research group of the Baku State University into the EU research area and the participation of this group in future EU projects

For 36 months the implementation of the project agreement made significant strides in direction of involving Nano Center - Baku State University in the European scientific Area and in integrating scientific interest of this center with European Research groups. During the project implementation, it was carrying out six management meetings (1-2 December 2010, Szeged, Hungary; 27 May 2011, Oulu, Finland; 30 September, 2011, Baku, Azerbaijan, 30 September 2012, Oulu, Finland, 22 March 2013, Szeged, Hungary, 22 October 2013, Szeged, Hungary). In this management meetings was discussed Contract requirements, Gender Strategy, management system, project management, organization of seminars, workshops and trainings, the general aspects of Agenda of Workshops&Trainings, the results of last 6 month work period and planning for common yearly and detailed 6 month works. It was defined the group profiles for each participating country concerning state-of-the-art nanotechnology research, nanoscience policies and key actors in the fields of electronics and photonics. It was studying the nanotechnology map research capabilities of the Nanocenter, BSU, Azerbaijan and partner countries. These indicators included macroscopic economic data such as economic growth, trade and R&D expenditure, human resources for R&D, finance resource for funding for research and innovation projects, etc. During the project implementation in framework WP3 Networking, was bought domain name www.napep.net for NAPEP project. All project Events data was collected and published on webpage. News about NAPEP project published on page News. For establishing future sustainability development research in area of nanotechnology is very important establishing of connection between research group of project partners, universities, SME`s, industry and service company of partner countries. Such type of connection carrying out in during all project implementation. For this purpose was collected information about Nanotechnology related research, production and Service Company in all partner countries. During the project implementation it was defined the common research interest of partner Universities. The young and senior Researchers were presented the results of original works on NAPEP Workshops. In such type of meetings it was discussed the perspective topic in area Nanoscience and nanotechnology for future collaboration. In Research planning meetings (Szeged, 24 March 2012) it was defined the main direction of future collaboration. In minutes of meeting discussion the project partners decided that future collaboration of partner groups in FP7 and Horizon2020 framework programs will be in following directions: **Developing of materials for Solar cell elements, Materials for hydrogen generation, Developing sorbents on base of new layered nanocomposites, new composite materials on base of carbon nanotubes and polymers.** It was the created topics for young researcher’s personal trainings. Main trainings in area of synthesizing and investigation of nanomaterials characteristics doing on second part of project implementation. On NAPEP Workshops and Trainings mainly were participated young researchers from partner universities and representatives of SME and industry. The main materials of NAPEP Workshops, Trainings and management meetings materials were published on Project web-site. Information about this event was published on newspapers and was disseminated through media outlets. In this event mainly was participated young researchers from partner Universities. The main part (more than 35% ) of project participants was Female personal.

- A description of the main S&T results/foregrounds (not exceeding 25 pages),

**Results related to the University of Oulu**

***Oulu introduction***

The main scientific expertise of the Oulu node in the NAPEP project is in materials science and technology with the primary aim to implement novel materials in electrical, electromechanical, electrochemical, sensor, catalytic as well as in photocatalytic applications. Nanomaterials such as carbon nanotubes, titanate and titania nanowires, metal nanowires and nanotubes and their derivatives have been representing the main stream of research of the group for more than 10 years. Besides materials research, a number of different enabling technologies have been used and also developed to allow demonstration for proof-of-concept studies including carbon nanotube cooled Si microchips,[2] soft flexible conformal carbon nanotube contact electrodes,[3] inkjet printed transparent conductive coatings,[4] transistors[5] and sensors,[6] photocatalytic converters[7] and antimicrobial coatings,[8] among many other devices and components that were partially developed earlier in collaboration with the members of the Szeged node.

Accordingly, our role in the NAPEP project was to share our knowledge with the Baku team and extend our scientific efforts with the research groups by continuing the already ongoing research, which is also supported by other projects[9] of the Oulu node. As a result of the collaborative effort and external support received from other projects, knowledge transfer among the partners was initiated and accomplished, and scientific reports in peer-reviewed international journals were published (some of them are under review or in the preparation phase at the moment).

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[2] K. Kordás, G. Tóth, P. Moilanen, M. Kumpumäki, J. Vähäkangas, A. Uusimäki, R. Vajtai, P.M. Ajayan, Chip cooling with integrated carbon nanotube microfin architectures, App. Phys. Lett. 90 (2007) 123105.

[3] G. Toth, J. Mäklin, N. Halonen, J. Palosaari, J. Juuti, H. Jantunen, K. Kordas, W. G. Sawyer, R. Vajtai, P. M. Ajayan, Carbon Nanotube Based Electrical Brush Contacts, Advanced Materials, 21 (2009) 2054.

[4] T. Mustonen, K. Kordás, S. Saukko, G. Tóth, J. S. Penttilä, P. Helistö, H. Seppä, H. Jantunen, Inkjet printing of transparent and conductive patterns of single-walled carbon nanotubes and PEDOT-PSS composites, physica status solidi (b) 244, (2007) 4336.

[5] E. Gracia, G. Sala, F. Pino, N. Halonen, J. Luomahaara, J. Mäklin, G. Tóth, K. Kordás, H. Jantunen, M. Terrones, P. Helistö, H. Seppä, P.M. Ajayan, R. Vajtai, Electrical transport and field effect transistors using inkjet printed SWCNTs films having different functional side groups, ACS Nano, 4 (2010) 3318.

[6] J. Kukkola, M. Mohl, A.-R. Leino, G. Tóth, M.-C. Wu, A. Shchukarev, A. Popov, J.-P. Mikkola, J. Lauri, M. Riihimäki, J. Lappalainen, H. Jantunen, K. Kordás, Inkjet-printed gas sensors: metal decorated $WO_3$ nanoparticles and their gas sensing properties, J. Mater. Chem., 22 (2012) 17878.

[7] M.-C. Wu, J. Hiltunen, A. Sapi, A. Avila, W. Larsson, H.C. Liao, M. Huuhtanen, G. Tóth, A. Shchukarev, N. Laufer, A. Kukovecz, Z. Kónya, J.-P. Mikkola, R. Keiski, W.-F. Su, H. Jantunen, K. Kordás, Nitrogen-doped $TiO_2$ Anatase Nanofibers Decorated with Noble Metal Nanoparticles for High-efficiency Photocatalytic Hydrogen Generation, ACS Nano 5 (2011) 5025.

[8] Mohl, M; Dombovari, A; Tuchina, ES; Petrov, PO; Bibikova,OA; Skovorodkin, I; Popov, AP; Rautio, A-R; Sarkar, A; Mikkola, J-P; Huuhtanen, M; Vainio, S; Keiski, RL; Prilepsky, A; Kukovecz, A; Konya, Z; Tuchin, VV; Kordas K, Titania Nanofibers in Gypsum Composites: An Antibacterial and Cytotoxicology Study (accepted in J. Mater Chem. B)

[9] Implementation of highly efficient $TiO_2$ based photocatalytic nanomaterials, Imphona (2011-2014, the Finnish Funding Agency for Technology and Innovation, Tekes); Autonomous R2R systems, AutoSys (roll-to-roll printed solar cells, 2011-2014, Tekes); Novel catalyst materials based on robust CNT membranes (2009-2012, AF)

Apart from the extensive number of delivered lectures and talks on seminars and workshops (reported also in Deliverable D7.3)[10] we have been organizing practical trainings for the students of the Baku State University and University of Szeged. The purpose of the trainings was to show the operation and use of equipment necessary for microelectronics and device fabrication as well as for nanomaterials synthesis and modification. After a short theoretical course[11] held in Oulu, Finland in May 2011, a practical exercise and laboratory work was arranged in the premises of the Microelectronics and Materials Physics Laboratories and in the Center of Microscopy and Nanotechnology, where the students themselves could carry our experiments on carbon nanotube synthesis (chemical vapor deposition from xylene-ferroce precursors, inkjet printing nanoparticles of $SnO_2$ and $WO_3$ on Si microchips, clean room fabrication of Si chips (complete lithography line including physical vapor deposition, plasma-enhanced chemical vapor deposition, reactive ion etching, spin coating, mask alignment and chemical wet etch) and electron microscopy (transmission electron microscopy and scanning electron microscopy equipped with energy dispersive X-ray spectroscopy).

***Localized catalytic oxidation of carbon nanotubes*** [12]

Research on the stability of carbon nanotubes in the presence of metallic and/or metal oxide nanoparticles (decorating the CNT surface) has revealed the carbonaceous surface is prone to oxidation at moderate temperatures as compared to pure carbon nanotubes. For instance, oxidation of CNTs in air can start even below 300 °C when the nanotubes are in contact with cobalt oxides (Fig. 1.1).

[10] Krisztián Kordás: Macroscopic carbon nanotube fibers; Melinda Mohl: Flexible electrodes prepared by reactive inkjet printing; Krisztian Kordas: Synthesis and applications of photocatalytic nanomaterials; Niina Halonen: Synthesis of Carbon Nanotubes; Anne-Riikka Leino: Catalytic digestion of carbon nanomaterials; Aron Dombovari: Aligned Carbon Nanotube (CNT) Growth at Low Temperature; Melinda Mohl: Preparation of nanowire devices for transparent and/or flexible electronics; Anne-Riikka Leino: Thermal stability of metal nanoparticle decorated support materials; Niina Halonen: Patterned CNT forests for electrode applications; Jarmo Kukkola: Gas sensors based on WO3 nanoparticles; Jani Mäklin: Electrical and thermal properties of carbon nanotube films; Krisztián Kordás: Carbon nanotubes and their applications; Aron Dombovari: Transparent and Flexible Conductive Films Prepared by Reactive Inkjet Printing; Melinda Mohl: Novel type of Transparent Electrodes to replace ITO films

[11] Krisztian Kordas: State-of-the-art methods in micro- and nanoelectronics; Janne Remes: Focused ion beam processing; Geza Toth: Finite-element modeling for micro- and nanosystems; Jarmo Kukkola, Jani Mäklin: Gas sensing with nanomaterials; Niina Halonen: Carbon nanotubes and their applications

[12] Leino, AR; Mohl, M; Kukkola, J; Maki-Arvela, P; Kokkonen, T; Shchukarev, A; Kordas, K Low-temperature catalytic oxidation of multi-walled carbon nanotubes, Carbon 57 (2013) 99.; Anne-Riikka Rautio, Olli Pitkänen, Topias Järvinen, Ajaikumar Samikannu, Niina Halonen, Melinda Mohl, Jyri-Pekka Mikkola, Krisztian Kordas, Thin film electric double-layer capacitors based on nanostructured MWCNTs (under preparation)

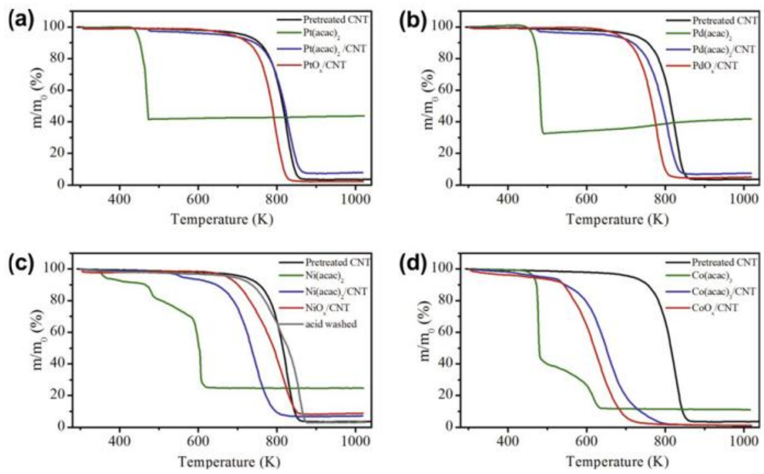



**Figure 1.1** Thermal gravimetric analysis of CNTs decorated with different kinds of metal organic and metal oxide nanoparticles [Leino, AR; Mohl, M; Kukkola, J; Maki-Arvela, P; Kokkonen, T; Shchukarev, A; Kordas, K Low-temperature catalytic oxidation of multi-walled carbon nanotubes, Carbon 57 (2013) 99].

On the other hand, the stability of CNTs may be also compromised in reductive environment. Experiments showed that Pt and Pd nanoparticles can decrease the temperature of carbon gasification (Fig. 1.2).

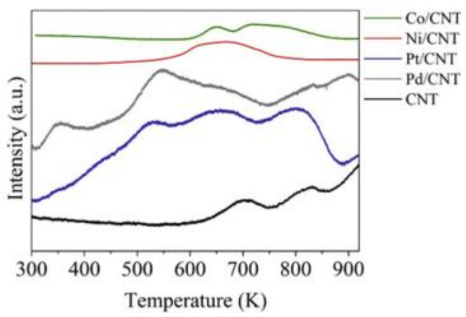
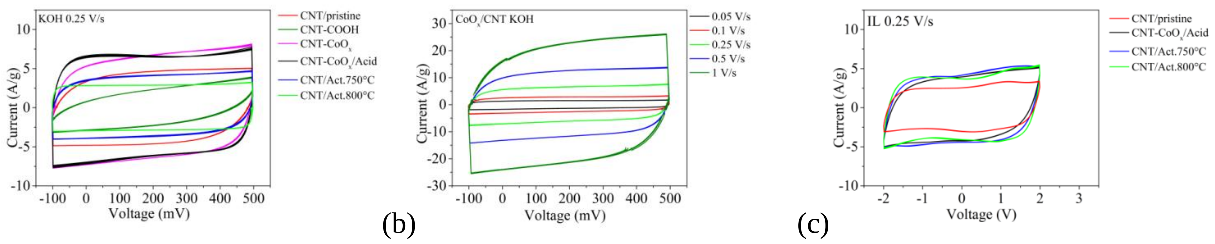



**Figure 1.2** Temperature programmed reduction profiles of 5 different CNT samples showing differen $H_2$ consumption behavior as a function of temperature [Leino, AR; Mohl, M; Kukkola, J; Maki-Arvela, P; Kokkonen, T; Shchukarev, A; Kordas, K Low-temperature catalytic oxidation of multi-walled carbon nanotubes, Carbon 57 (2013) 99].

Exploiting the localized catalytic oxidation of the nanotubes with the use of $CoO_x$ nanoparticles gave the intuition to increase the specific surface area of the nanotubes and then test the modified materials in supercapacitor electrodes, viz. the large specific surface area of electrically conductive materials is one of the most important property that can improve the specific capacitance. The nanostructured (i.e. locally oxidized nearby the metal oxide nanoparticles) carbon nanotubes showed high specific capacitance (~25 F/g in aqueous KOH and ~15 F/g in triethylsulfonium bis(trifluoromethylsulfonyl)imide room temperature ionic liquid) making them promising candidates for novel electrode materials.




(a) (b) (c)

**Figure 1.3** (a) Cyclic voltammetry (*C-V*) curves of electric double layer capacitors made of nanostructured multi-walled CNT films measured in KOH electrolyte: pristine (CNT/pristine, red), carboxyl functionalized (CNT-COOH, dark green), $CoO_x$ decorated (CNT-$CoO_x$, magenta), $CoO_x$ decorated and acid washed (CNT-$CoO_x$/acid, black), $CO_2$ activated at 750°C (CNT/Act.750°C, blue) and at 800°C (CNT/Act.800°C (light green). (b) *C-V* curves of symmetric $CoO_x$/MWCNT electrodes measured at different charge/discharge rates in KOH electrolyte. (c) *C-V* curves of symmetric CNT/pristine (red), CNT-$CoO_x$/acid (black), $CO_2$ activated at 750°C (CNT/Act.750°C, blue) and at 800°C (CNT/Act.800°C (light green) carbon nanotube thin film in triethylsulfonium bis(trifluoromethylsulfonyl)imide ionic liquid electrolyte measured (c) from -2 to 2 V and (d) from -2 to 3V [Anne-Riikka Rautio, Olli Pitkänen, Topias Järvinen, Ajaikumar Samikannu, Niina Halonen, Melinda Mohl, Jyri-Pekka Mikkola, Krisztian Kordas, Thin film electric double-layer capacitors based on nanostructured MWCNTs (under preparation)].

**Photocatalytic and catalytic converters based on $TiO_2$ nanowires and their composites[13]**

Immobilization of photocatalytic (and also catalytic) materials is of practical importance since one can avoid filtration of the active semiconducting solids after being used in liquid phase reactions. Furthermore, surface bound catalysts in the gas phase allow application of the materials without the need of fluidization and can allow also applications in atmospheric conditions even in our daily life. The antimicrobial behavior of $TiO_2$ surfaces have been proven and exploited for more than ten years. Such property is based on the oxidative effect of hydroxyl radicals that form on the surface of the photocatalyst after the reaction of surface adsorbed water molecules with photogenerated electrons and holes. The process has great practical relevance in surface disinfection in domestic and public facilities but also even in healthcare settings. One of the major hurdles of extensive use is the lack of technology for producing very large footprint area coatings, in which the photocatalytic nanoparticles are properly bound, and the binder is remaining stable for longer periods of time. The aims of our studies thus were to produce coatings that are preferably inorganic (to avoid photocatalytic decomposition of the binder matrix), have reasonable mechanical integrity and are of low cost (to ensure future exploitation). After testing a number of different materials combinations, composites of gypsum with nanowires of $TiO_2$ based photocatalytic nanoparticles were found as the most promising candidates for the task (Fig. 1.4).

[13] Mohl, M; Dombovari, A; Tuchina, ES; Petrov, PO; Bibikova,OA; Skovorodkin, I; Popov, AP; Rautio, A-R; Sarkar, A; Mikkola, J-P; Huuhtanen, M; Vainio, S; Keiski, RL; Prilepsky, A; Kukovecz, A; Konya, Z; Tuchin, VV; Kordas K, Titania Nanofibers in Gypsum Composites: An Antibacterial and Cytotoxicology Study (accepted in J. Mater Chem. B); Anne-Riikka Rautio, Päivi Mäki-Arvela, Atte Aho, Kari Eränen, Krisztian Kordas Chemoselective hydrogenation of citral by Pt and Pt-Sn catalysts supported on $TiO_2$ nanoparticles and nanowires (under review in Catalysis Today)

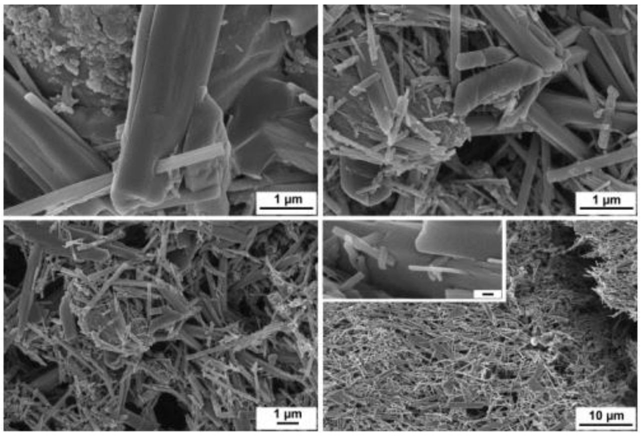



**Figure 1.4** Scanning electron micrographs of $TiO_2$-gypsum inorganic composite films [Mohl, M; Dombovari, A; Tuchina, ES; Petrov, PO; Bibikova,OA; Skovorodkin, I; Popov, AP; Rautio, A-R; Sarkar, A; Mikkola, J-P; Huuhtanen, M; Vainio, S; Keiski, RL; Prilepsky, A; Kukovecz, A; Konya, Z; Tuchin, VV; Kordas K, Titania Nanofibers in Gypsum Composites: An Antibacterial and Cytotoxicology Study (accepted in J. Mater Chem. B, DOI: 10.1039/C3TB21644F)]

When illuminated with blue light, the composite surfaces inhibit the proliferation of staphylococcus aureus bacteria (both methicillin resistant and sensitive strains) as shown in Fig. 1.5. Since the composite films may be cast, pained or even molded in various shapes and forms, the application of such antimicrobial surfaces is rather straightforward and expected to become general in the future.

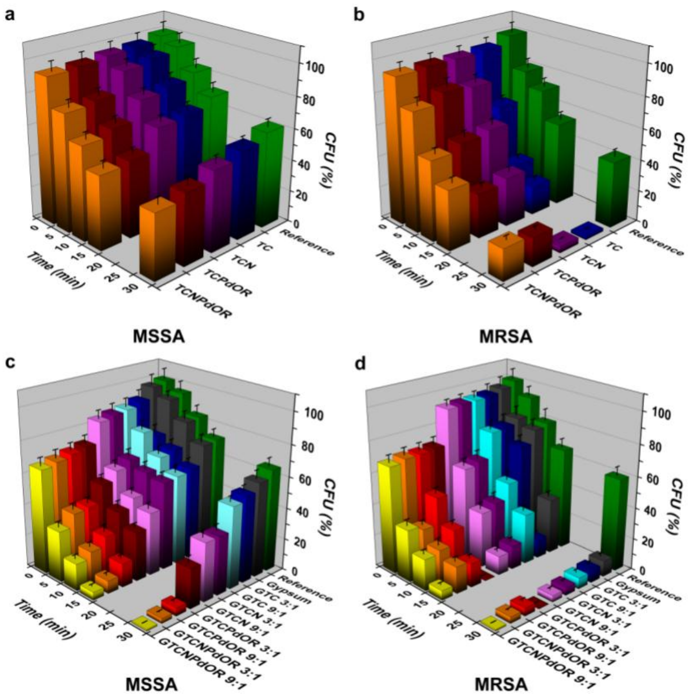



**Figure 1.5** Antimicrobial properties of titania photocatalysts (a), (b), and gypsum-titania nanocomposites (c), (d) under blue light exposure. [Mohl, M; Dombovari, A; Tuchina, ES; Petrov, PO; Bibikova,OA;

Skovorodkin, I; Popov, AP; Rautio, A-R; Sarkar, A; Mikkola, J-P; Huuhtanen, M; Vainio, S; Keiski, RL; Prilepsky, A; Kukovecz, A; Konya, Z; Tuchin, VV; Kordas K, Titania Nanofibers in Gypsum Composites: An Antibacterial and Cytotoxicology Study (accepted in J. Mater Chem. B, DOI: 10.1039/C3TB21644F)]

Nanostructured $TiO_2$ materials are also useful as catalyst support in heterogeneous chemical reactions. $TiO_2$ is an n-type semiconductor, which can act as an electron donor or hole acceptor (nucleophile) but can be also as a rectifier in contact with metal nanoparticles having large work function (typically noble metals such as Pt or Pd). For this reason, $TiO_2$ can take part in the electron transfer and storage in many ways during the chemical reactions making this material an attractive choice of support. $TiO_2$ surfaces/coatings and nanoparticles are in use for decades, however nanowires were not explored yet. Therefore, in one of our studies, we have used Pt catalyst nanoparticles supported on $TiO_2$ nanoparticles and also nanowires to find out what the main differences are between them. Hydrogenation of citral as a model reaction was tested. Because of the alkaline nature (with weak basic sites) of $TiO_2$ nanowires, the catalyst based on the nanowires proved to have higher activity and better selectivity towards citronellal and then subsequently to dimethyloctanol than the catalyst based on $TiO_2$ nanoparticle support (which was not selective at all producing instantly citronellol, dimethyloctanal and dimethyloctanol.

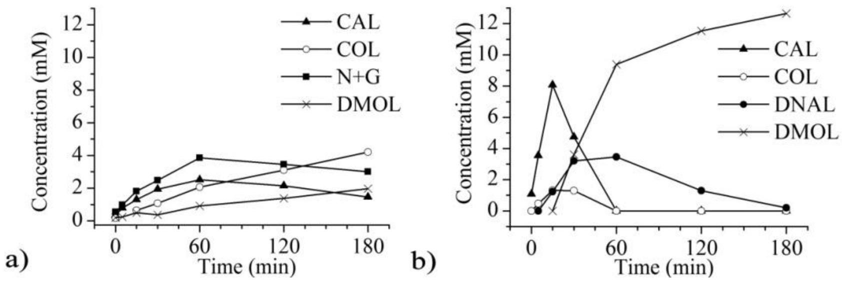



**Figure 1.6** Product distribution in citral hydrogenation over a) Pt/$TiO_2$ NP and b) Pt/$TiO_2$ NW in toluene [Anne-Riikka Rautio, Päivi Mäki-Arvela, Atte Aho, Kari Eränen, Krisztian Kordas Chemoselective hydrogenation of citral by Pt and Pt-Sn catalysts supported on $TiO_2$ nanoparticles and nanowires (under review in Catalysis Today)]

### *Transparent conductive coatings*[14]

Transparent conductive films (TCFs) play an important role in devices with displays and touch screens like our flat panel TV sets, computer displays, cellular phones but also used as heating elements in wind shields of cars or top electrodes in organic solar cells. The conventional indium tin oxide (ITO) based coatings applied today has two major drawbacks. One is the limited amount of raw materials which is expected to run out in 20 years or so, while the other one is the rigidity of the coatings disabling its use in flexible devices. Films and

[14] M. Mohl, A. Dombovari, K. Kordas, Scalable Fish Scale Like Transparent Copper Electrodes by Reactive Inkjet Printing and Electroless Plating (under preparation)

various patterns of metal nanoparticles and nanotubes along with carbon nanotubes represent the second generation of TCFs. These devices typically suffer from reliability related problems. Our aim was here thus to develop thin film microscopic grid pattern structures without using lithography and associated physical vapor deposition techniques, i.e. the technology must rely on additive printing methods that are cost effective and allow mass production of electrically and mechanically reliable coatings.

Metal films can be deposited by the means of wet chemical reactions on a number of different surfaces. Cations of metals that are typically complexed with EDTA or ammonia are easy to be reduced with alcohols, sugars and aldehydes to form metallic deposits. The strategy thus to prepare patterns of the metallic films is given by depositing the reactive solution by inkjet printing. Palladium and silver micropatterns were made this way on the surface of polymers. To improve the conductance of the thin film patterns, in a subsequent process step, copper film of ~50 nm thickness was chemically plated on the areas having the pre-deposited Pd or Ag.

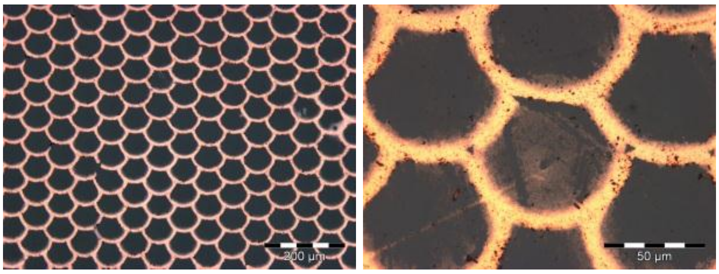



**Figure 1.7** Optically transparent and electrically conductive thin film pattern of copper plated on a self-similar silver pattern. The honey-comb structure is obtained by utilizing the coffee-stain ring effect of the drying inkjet deposited reactive silver containing solution [M. Mohl, A. Dombovari, K. Kordas, Scalable Fish Scale Like Transparent Copper Electrodes by Reactive Inkjet Printing and Electroless Plating (under preparation)].

The method is proved to be suitable for preparing high-definition patterns of good optical transmittance ($T > 60\%$) and low sheet resistance ($R_s < 10\ \Omega/sq$), good adhesion and excellent mechanical integrity clearly competing with the state-of-the-art coatings.

Results related to the University of Szeged

***Szeged introduction***

The key expertise of the Szeged node in the NAPEP project was the synthesis and property tailoring of one dimensional inorganic nanostructures which were to be tested as supports in various photovoltaic and materials science applications by the partners. Moreover, the Szeged team was responsible for organizing the 5$^{th}$ Szeged International Workshop on Advances in Nanoscience (SIWAN 2012), an international conference with close to 200 participants which served as a dedicated dissemination event for NAPEP.

The training and brokerage events organized by the Szeged team have assisted the NAPEP partners, in particular, researchers of the Baku State University to establish contacts with the following industrial and scientific stakeholders working outside the project:

- President of the Szeged Division of the Hungarian Academy of Sciences
- Dean of the Faculty of Technology, University of Novi Sad, Serbia
- Europe Match GmbH Hungarian Branch, a company utilizing the latest results of materials science research in the production of quality matches
- Nanobact Ltd, a company specialized in manufacturing silver nanoparticle based antimicrobial products
- CEO of Auro-Science Ltd, a company active in the production scale-up and commercialization of various nanotechnology products including titanate nanotubes, titanate nanowires and zero-valent iron nanoparticles
- Golder Associates, Hungarian Branch: a member of a multi-national network of companies working in evironmental assessment and remediation in general, and in developing world-leading solutions for nanotechnology-based remediation methods in particular.
- Unichem Ltd, a company utilizing the latest results of materials science research in providing water treatment solutions.

It is expected that these new contacts will help the azeri colleagues in exploiting the results of NAPEP, developing new projects and integrating successfully into forthcoming Horizon 2020 programs.

The scientific output of the Szeged node was summarized in five published papers so far which are summarized below. Three more papers based on results achieved in the later part of the project are under preparation now.

***Tailoring the properties of MWCNTs***

Multiwall carbon nanotubes (MWCNTs) consist of coaxially stacked cylindrical graphene sheets capped by half fullerenes at both ends. They feature a hollow internal channel with a diameter of 3-6 nm, a typical outer diameter between 10-30 nm and lengths above 1 micrometer[15]. Their excellent electrical and thermal conductivity, high stiffness and axial strength have attracted lots of attention from the scientific community in the past two decades[16]. The wholesale price of MWCNTs has recently dropped below 200 USD/kg and therefore, carbon nanotubes are no longer merely objects of scientific interest but a raw material for the production industries. Consequently, it is important to expand the toolset of materials science with methods capable of tailoring the properties of MWCNTs in a cheap and scalable way.

[15] Iijima S. Helical microtubules of graphitic carbon. Nature 1991; 354, 56-58.
[16] Kavan L, Dunsch L, Kataura H. Electrochemical tuning of electronic structure of carbon nanotubes and fullerene peapods. Carbon 2004;42:1011–9. Zubizarreta L, Gomez EI, Arenillas A, Ania CO, Parra JB, Pis JJ. H2 storage in carbon materials, Adsorption 2008; 14, 557-566. Munoz E, Ruiz-Gonzalez ML, Seral-Ascaso A, Sanjuan ML, Gonzalez-Calbet JM, Laguna M, de la Fuente, GF. Tailored production of nanostructured metal/carbon foam by laser ablation of selected organometallic precursors. Carbon 2010; 48, 1807-1814.

Solid state transformations are important in several fields of technological chemistry including ceramics synthesis and catalyst support manufacture[17]. In particular, ball milling is used by several industries including ceramics, paint manufacturing, pharmaceutics and construction. Variants of the ball milling process have been previously applied to modify the length[18], particle size distribution[19], hydrogen adsorption properties[20] and lithium intercalation capacity[21] of carbon nanotubes as well as to perform carbon nanoparticle synthesis[22]. Planetary ball milling is particularly suitable for improving the dispersion of MWCNTs in aluminum[23] and polymer matrices. Despite its many applications and high potential for serving as an industrially feasible technology for nanotube property tailoring[24] a generally accepted model describing all energy transfers happening during the milling of carbon nanotubes is not yet available. However, attempts have been made to describe the energetics of high-energy milling[25] and planetary ball milling[26] in general.

Our goal in was to provide experimental data that can support further model development work in the field. In particular, we report the dependence of average multiwall nanotube length, specific surface area, pore size distribution and surface fractal dimension on the most important process parameters of a planetary ball mill. These morphological descriptors were determined by transmission electron microscopy (TEM) image analysis and nitrogen adsorption isotherm analysis. Carefully controlled and described experimental conditions facilitate the reproduction of the reported results.

Planetary ball milling of the multiwall carbon nanotube starting material invariably resulted in an increase in

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Nouni N, Ziaei-Rad S, Adibi S, Karimzadeh F. Fabrication and mechanical property prediction of carbon nanotube reinforced Aluminum nanocomposites. Materials and design 2012; 34, 1-14.

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the apparent density of the material. On the basis of earlier low-impact milling studies this suggests that the nanotubes were cut into smaller pieces corresponding to a more compact macroscopic structure. The morphology of this material was studied in detail by TEM and nitrogen adsorption analysis. The detailed parameters of the discussed milling series are listed in Table 2.1 and 2.2.

| | Milling series | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| $W_d$ [rpm] | 150, 200, 250, 300, 350, 400, 450, 500, 550, 600 | 350 | 350 | 350 | 350 |
| t [min] | 60 | 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 | 60 | 60 | 60 |
| $N_b$ [pcs] | 15 | 15 | 5, 10, 15, 20, 25 | 40, 80, 120, 160, 200 | see Table 2. |
| $d_b$ [mm] | 10 | 10 | 10 | 5 | 5&10 |

Table 2.1. Overview of the milling process parameters varied in this study. $W_d$ is the rotational speed of the main disc in rpm, t is the milling time in minutes, $N_b$ is the number of balls and $d_b$ is the diameter of grinding balls in mm.

| Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Ratio of ball's mass | 1:0 | 10:1 | 4:1 | 2:1 | 1:1 | 1:2 | 1:4 | 1:10 | 0:1 |
| $N_b$ of 10 mm | 15 | 14 | 12 | 10 | 8 | 5 | 3 | 1 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ball (pcs) | | | | | | | | | |
| $N_b$ of 5 mm ball (pcs) | 0 | 8 | 24 | 40 | 60 | 80 | 96 | 112 | 120 |

Table 2.2. Details of the large to small ball ratio variation experiments (see Table 1E for the other process parameters).

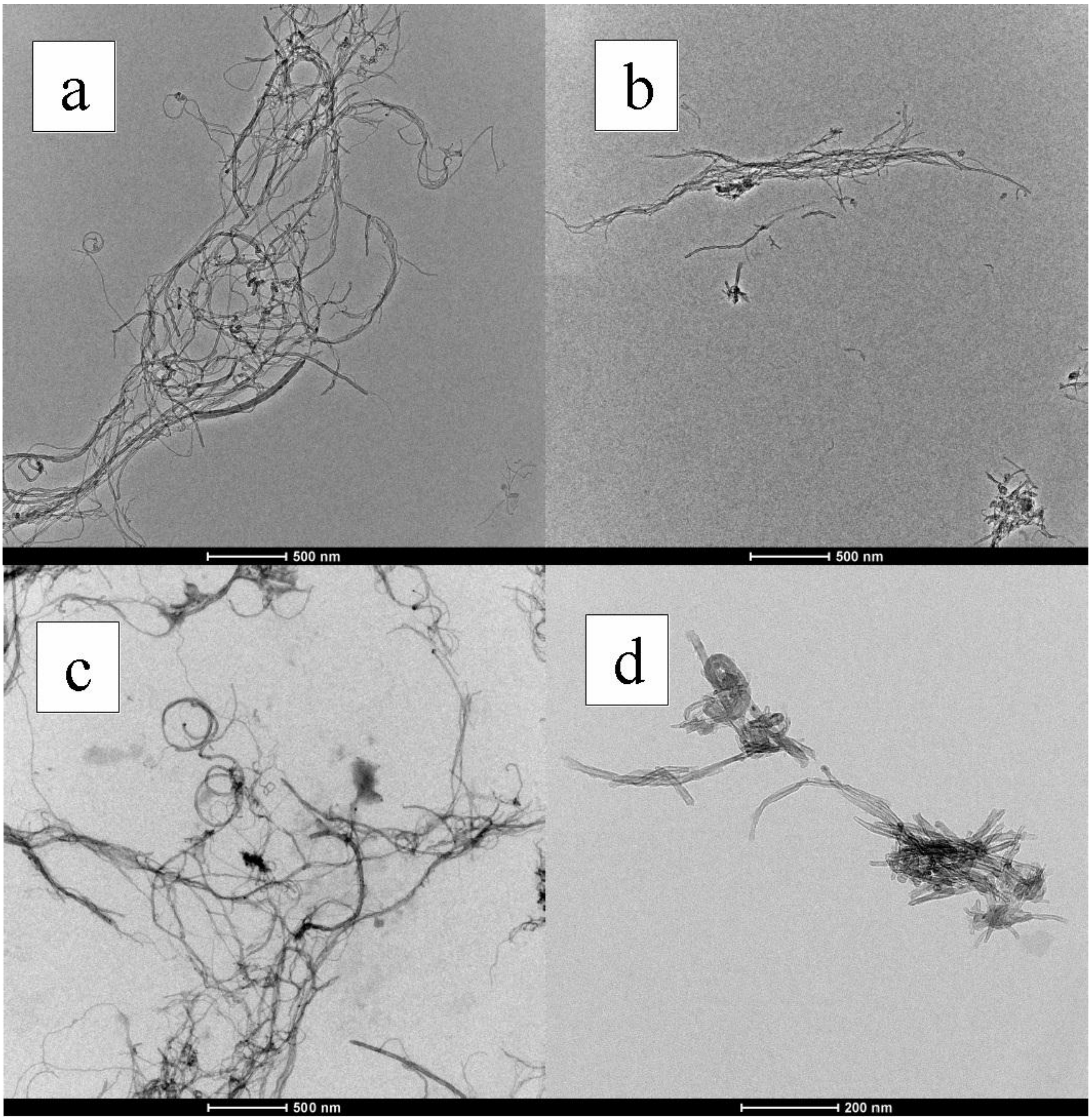

Figure 2.1. Characteristic TEM images of the carbon nanotubes subjected to various milling treatments. Images corresponding to series A 150 rpm and 350 rpm are depicted in parts (a) and (b), respectively. Parts (c) and (d) are typical for series B 5 min (c) and 60 min (d) experiments, respectively.

Characteristic TEM images illustrating the changes suffered by the nanotubes upon milling are depicted in Fig. 2.1. Increasing either the rotational speed of the planetary mill disk (Fig. 2.1a and 2.1b) or the duration of the milling (Fig. 2.1c and 2.1d) both yield shorter nanotubes. The apparent diameter of the tubes is unaffected by the milling and no amorphous carbon debris formation can be observed.

**Results related to the Baku State University**

***BSU Introduction***

Baku State University (BSU) is the most important research university of Azerbaijan. The Nanotechnology Center of BSU is a state-of-the-art facility with the potential to establish BSU as a regional leader in nanotechnology in the Southern Caucasus region. The following bottlenecks were identified by the experts of BSU to hinder this process:

- lack of organized, project-level collaborations with reseach institutes and universities based in the European Union,
- lack of experience in EU-financed networking (FP7, H2020),
- lack of access to the most recent methods and practices of contemporary materials science and nanotechnology research,
- shortage of young researchers who have their own international contact networks enabling them to pursue a PhD/postdoc career abroad and then transfer the obtained knowledge back to Azerbaijan.

The NAPEP project was able to contribute positively to all of these fields and significantly improve the chances of the Nanotechnology Center of BSU to be involved in successful H2020 applications. The particular research projects realized at BSU in the framework of NAPEP were designed to exploit the newfound access to state-of-the-art materials and technologies in the field of photovoltaics and materials science. A selection of the Baku results is provided in this section.

Silicon based solar cells have dominated the market but it is cost is high due to the manufacturing process. Therefore, the way forward is to develop thin films solar cells using low-cost attractive materials, grown by cheaper, and manufacturable techniques. The aim and objectives of this work is to develop high efficiency solar cell using electrodeposition (ED) technique. The material layers include CdZnSSe as the window materials, while the absorber material is CdTe. Fabricating a suitable devices for solar energy conversion (i.e. glass/conducting glass/window material/absorber material/metal) structure. Traditional way of fabricating this structure is to grow window material (CdS) using thermal evaporation and magnetron sputtering; absorber material (CdTe) using magnetron sputtering, MOVPE. Electrodeposition is a perspective competitor in thin film preparation because of several advantages such as the possibility for large-scale production, minimum waste of components and easy monitoring of the deposition process.This technique is generally less expensive than those prepared by the capital-intensive physical methods. One of the main disadvantages of electrochemical deposition is that the substrate must be conductive and its sheet resistance must be low.

***Semiconductor film deposition results***

Cyclic voltammetry was used to monitor the electrochemical reactions in solutions of $CdCl_2$, $ZnCl_2$, $Na_2S_2O_3$ and $Na_2Se_2O_3$, then in their combined solution of the same concentration and pH.

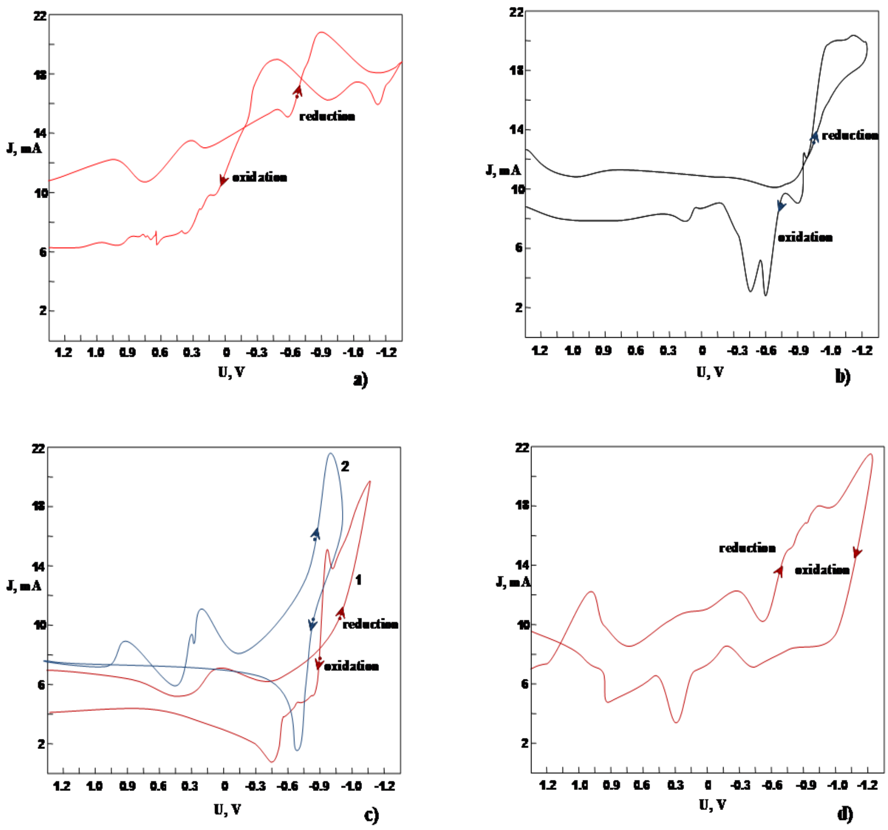


Figure 7.1 Characteristic voltammogramms

a) In the case of cadmium chloride solution, the current rise started at –0.15 V, followed by large reduction wave at –0.7 V. This response was associated with Cd reduction on substrate. The deposition reaction was reconfirmed by the reverse scan. The two stripping peaks at positive potential limits, 0.7-0.9 V indicated the oxidation of the cadmium compound.

b) Figure 7.1b shows the voltammogram recorded for $ZnCl_2$ on substrate. The forward scan showed a reduction potential starting at about –0.65V. This was due to the reduction process of Zn onto the working electrode. The reduction peak increased towards the more-negative region where hydrogen evolution also occurred. During the reverse scan, the oxidation wave of zinc could be seen starting at about –0.9 V. The oxidation peak clearly showed that the process was reversible whereby the deposited Zn dissolved upon reversing the potential.

c) The forward scan of $Na_2S_2O_3$ and $Na_2Se_2O_3$ solutions shows the cathodic current to start flowing at about –0.2-0.4V. The shoulder at –0.65-0.8V might be associated with the reduction of $Na_2S_2O_3$ and $Na_2Se_2O_3$ ions.

d) Figure 7.1d shows the cyclic voltammogram of the working electrode in the mixture of $CdCl_2$, $ZnCl_2$, $Na_2S_2O_3$ and $Na_2Se_2O_3$ salt.

Based on the above results, the voltammogram suggested that a deposition on the working electrode can be expected when the potentials above – 0.86 V are applied.

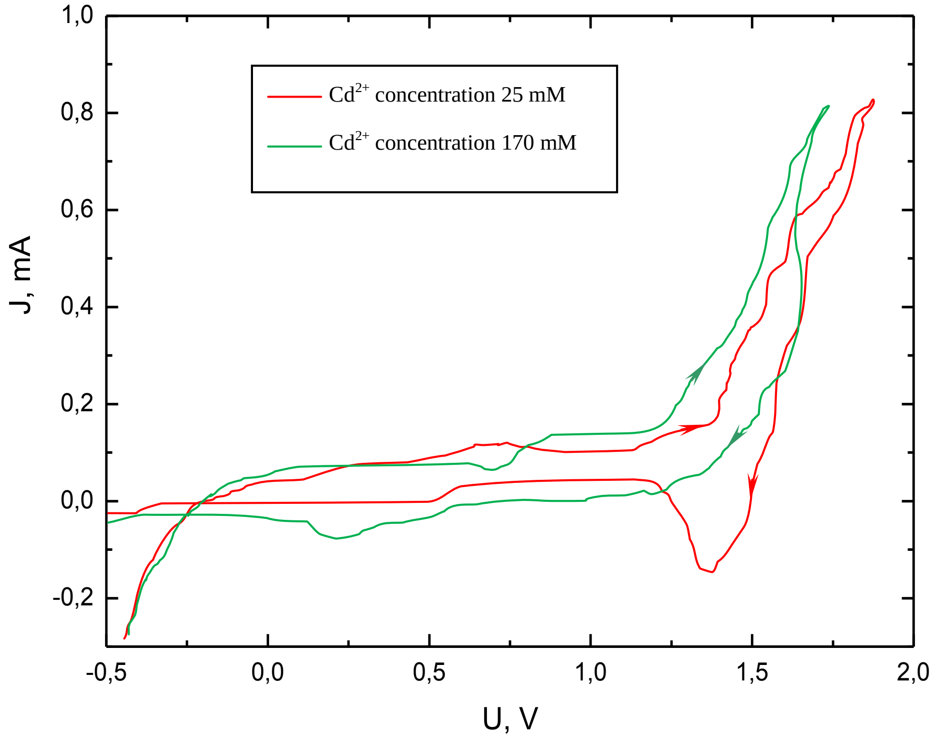


Figure 7.2 Typical CdTe layer electrodeposition voltammograms

| x (molar) (calculated data) | y (molar) (calculated data) | Results of atom absorbtion spectrometer (molar) | | Results of EDX method (molar) | | Crystalline parameters (?) |
|---|---|---|---|---|---|---|
| | | x | y | x | y | |
| 0.2 | 0.2 | 0.201 | 0.203 | 0.202 | 0.203 | 5.784 |
| 0.4 | 0.2 | 0.404 | 0.201 | 0.401 | 0.202 | 5.704 |
| 0.4 | 0.6 | 0.405 | 0.603 | 0.404 | 0.603 | 5.801 |
| 0.5 | 0.5 | 0.501 | 0.503 | 0.502 | 0.502 | 5.737 |
| 0.9 | 0.8 | 0.903 | 0.803 | 0.902 | 0.803 | 5.655 |

Table 7.1 XRF analysis results of CdZnSSe films

Figure 7.2 shows a typical voltammogram related to the electrodeposition of CdTe layers. The voltage scan was run between 0.1 to 1.7 V cathodic voltages. Te begins to be reduced when the current density starts to increase from cathodic voltages ~0.2V to ~1.4 V. In this region, elemental Te is free and the layer deposited is a mixture of CdTe and Te. A small hump is observed around 1.5 V, and deposition of mainly CdTe layer is expected beyond 1.6 V cathodic voltage as can be seen from the Figure. A rapid increase in current at ~1.6 V is due to the combination of deposition of elemental Cd and hydrogen evolution at the cathode.

The stoichiometry of the CdZnSSe layers was investigated using X-ray fluorescence and atom absoption spectroscopy in order to correlate the material and atomic percentages of individual elements. Table 7.1 shows the XRF analysis results for CdZnSSe films üith diferent composition.

The surface images in an area of 10 μm×10 μm of the thin films deposited at -0.86 V deposition potential is shown in Figure 7.3 below. It is established that at deposition potential U <-0.5 V the surface of the films was not very compact.

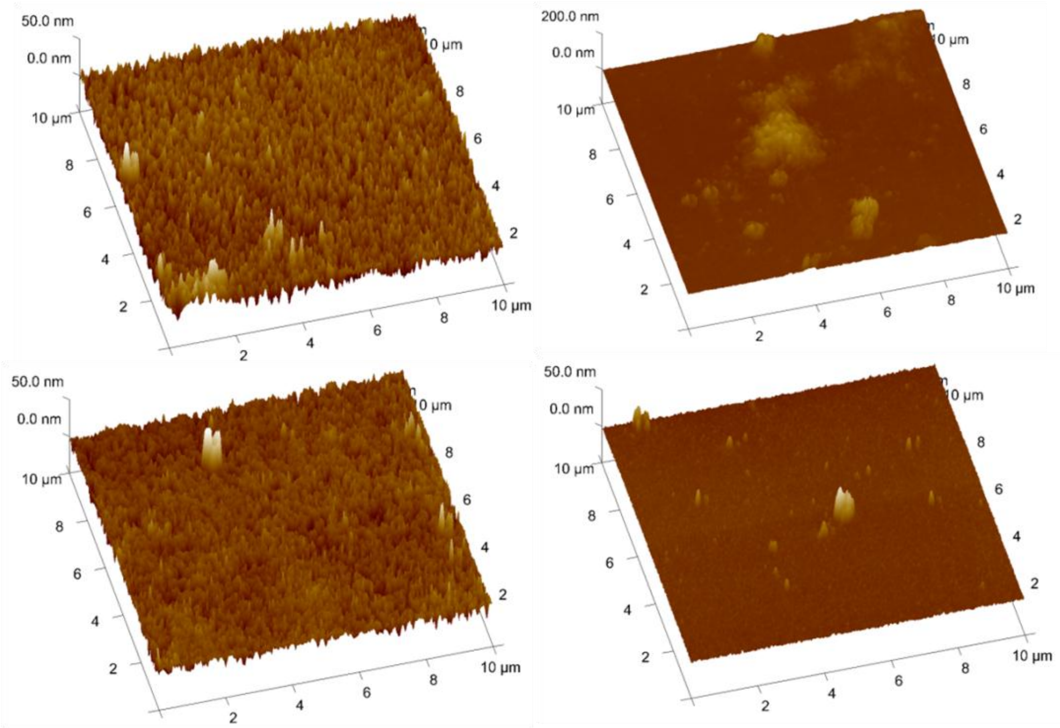

Figure 7.3 Characteristic AFM images of the samples

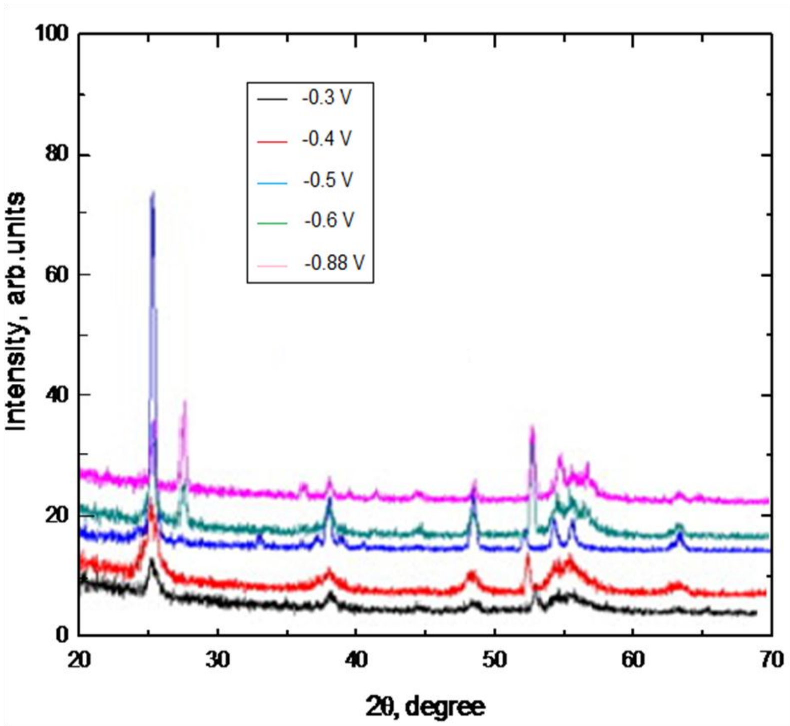


Figure 7.4 Typical XRD diffractograms of CdZnSSe films deposited on glass/$SnO_2$ substrate

The films were constituted by nano particles with an irregular size distribution, i.e. a lot of empty spaces could be seen between these particles AFM images of samples clearly show the conversion of nano particles into spherical grains that were quite uniform over the substrates, at increasing deposition potential. However, the film consisted of smaller and larger nano particles in deposition potential above –0.9 V. This might be due to the difference of rate of nucleation and growth. At the right hand side of the image, intensity strip is shown which indicates the height of the surface grain along Z-axis. The AFM picture shows the presence of high hills on top of a homogeneous granular background surface. The height of the hills was found to be decreased as the deposition potential increased up to -0.8V.

Figure 7.4 depicts the XRD diffractogram obtained for glass/SnO2 substrate, as deposited CdZnSSe films. From the Figure, the results show that the films have highly oriented crystallites with the hexagonal structure (Wurtzite type) with preferential orientation along the c-axis ((101) direction). Other peaks identified from the diffractogram are (100) and (110), as reported by most of the researchers in the field.

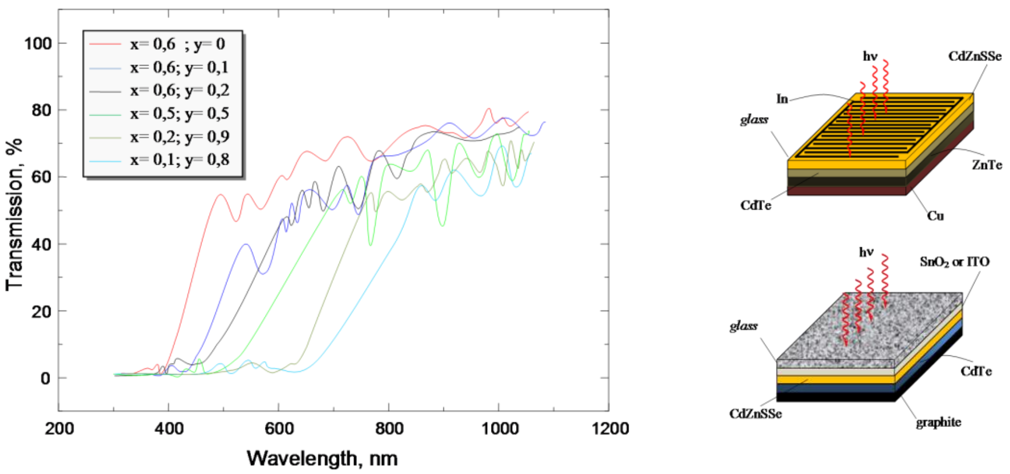


Figure 7.5 CdZnSSe film transparency results

These peaks were assigned according to the Joint Committee on Powder Diffraction Standards, JCPDS (00-001- 0780) data on hexagonal CdS-ZnSe alloys. As seen from figures, with increasing the deposition potential up to -0.88 V, the intensity of all the peaks increases and sharpens which indicates the formation of large grains and the improvement of bulk crystalline properties.

Figure 7.5 shows the room temperature transmission spectra for the different compositions of CdZnSSe films, measured in the wavelength range, 300-1800 nm. The transmittance of the films increased from 74% to 78% above the fundamental absorption edge with increase of Zn-content. It could be observed from that CdZnSSe films had a transparency in the visible region, which indicates better crystallinity in the films. Also, the fundamental absorption edge of the films shifted towards the shorter wavelength side with the increase of Zn-composition and decrease of Se-composition. The optical studies revealed that the absorption coefficient, α increased with the increase of composition up to 0.75. This shift in the α might be due to the increase of band gap as a function of composition. The bandgap of the CdZnSSe films were determined from extrapolation of the straight line section of the $(\alpha h\nu)^2$ versus hν curves. The observed bandgap for different x and y values for electrodeposited films were compared with other deposition techniques and found that the values are in good agreement.This reveals that uniform and device quality films can be prepared by electrodeposition technique

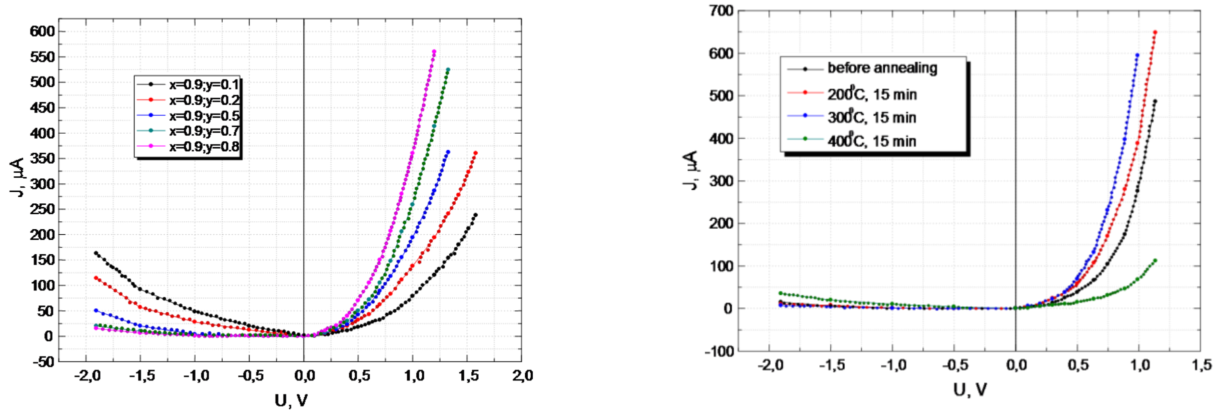


Figure 7.6 Current-voltage (I-V) characteristics

Figure 7.6 shows the of the as-deposited heterojunctions at room temperature. It is seen that, *I-V* characteristics of all the junctions are clearly asymmetric. The pass direction for the junctions corresponds to positive polarity of the external bias on the CdTe films. The rectification and barrier height in the as-deposited structures depends on the Zn and S concentrations.

The study of *I-V* characteristics shows, that the rectification coefficient and series resistance of junctions depends also on temperature and duration of the annealing in argon atmosphere. It is established, that the best rectification for junction is provided after the annealing at 200°C for 9-11 min. The rectification coefficient for annealed junctions was 1300-4000 for different film resistance of the junctions, as deduced from the *I-V* curves, was significantly decreased. This significant decrease in the series resistance of the junction indicates that the crystal quality of CdZnSSe annealed at 200°C is much improved, to enhance the device performance of the junctions. The forward current of the annealed structures are described by the exponential dependence up to the cut-off voltage. Observed direct bias of *I-V* characteristics for the compositions. When the annealing temperature was increased from 0 to 200°C, the series annealed junctions at different temperatures shows that forward currents mainly correspond to the recombination tunnel mechanism.

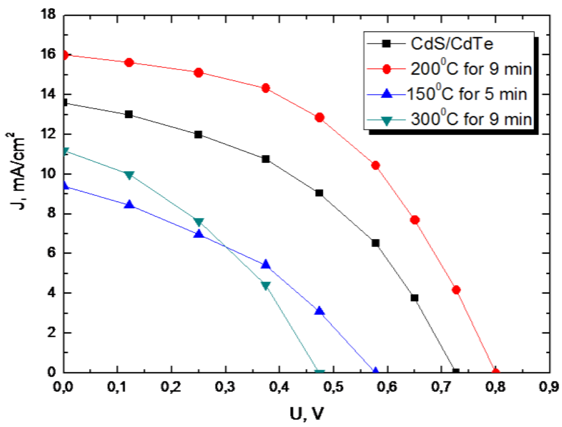

Figure 7.7 Current-voltage (I-V) characteristics

To investigate the effect of annealing on the photoelectrical parameters of junctions, we measured the short circuit photocurrent spectrum as shown in Figure. The photosensitivity sharply increases until annealing temperature of 200°C and exhibit high photosensitivity over a wide spectral range. The parameters of junctions did not show sign of any degradation processes over the investigation period that stretched over 1 year.

**ZnS nanocrystal synthesis**

• ZnS nanocrystals were synthesized through the reaction of zinc chloride with thiourea using Maleic anhydride–Octane-1–Vinylbutyl Ether terpolymer as the matrix.

• Transmission electron microscopy images of the nanoparticles show that the sizes of these nanoparticles do not exceed 5 nm.

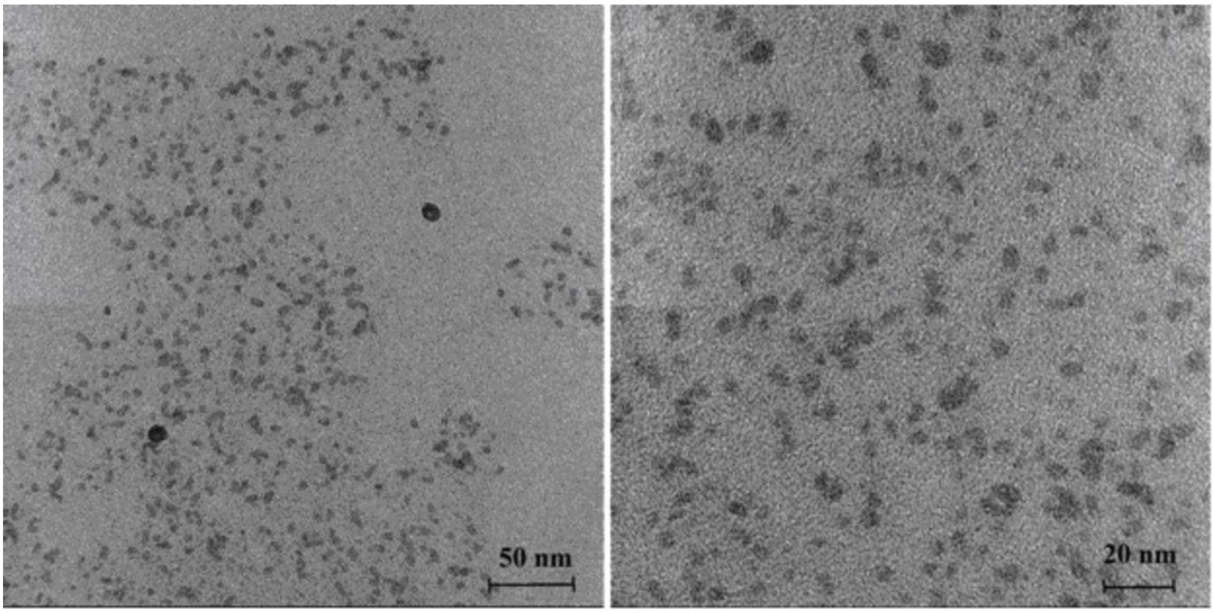


Figure 8.1 TEM images of TPL/ZnS nanocomposite.

• Optical Band gap and mean value of the diameter of the ZnS nanocrystals were deduced from the UV-visible results. Thus optical Band gap of the terpolymer/ZnS nanocomposite was approximately 3.74 eV, and this result is higher than that of bulk material (3.68 eV). This shifting to the higher energy state is the evidence of the formation of ZnS nanocrystals in terpolymer matrix. Besides, mean value of the diameter of the ZnS nanocrystal was found from the UV-visible results with Henglein equation. This average size was about 2.16

nm. The value of absorption for nanocomposite is 4.15 times more than the absorption value for terpolymer matrix.

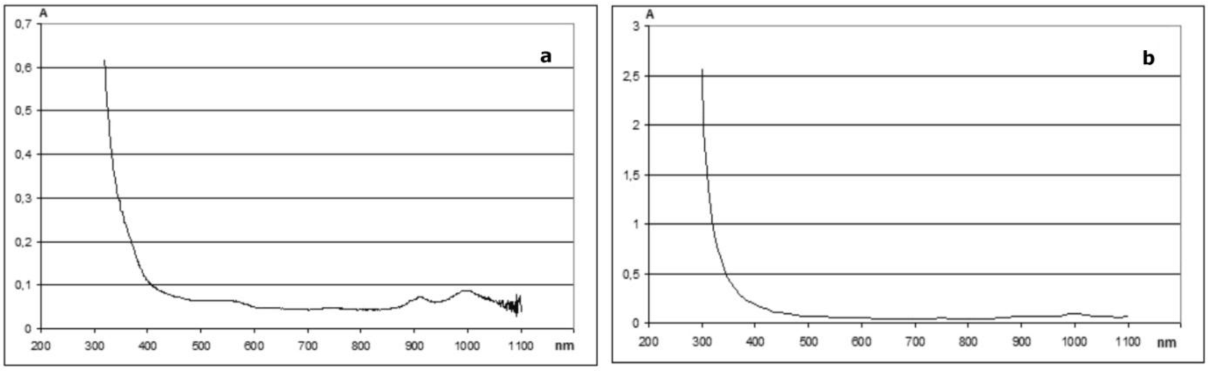


Figure 8.2 UV-visible absorption spectra of TPL (a) and TPL/ZnS (b) nanocomposite

• Energy dispersive X-ray results show that synthesized sample consists of carbon, nitrogen, oxygen, sulfur, chlorine and zinc.

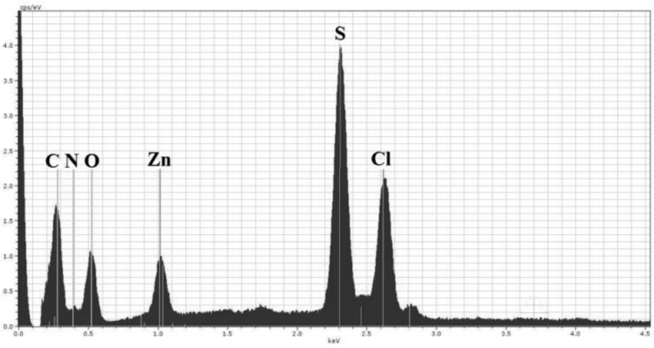


Figure 8.3 EDX spectrum of TPL/ZnS nanocomposite.

• Raman spectrum shows characteristic peaks for ZnS in 350, 700, 1020 and 1406 $cm^{-1}$ wave numbers

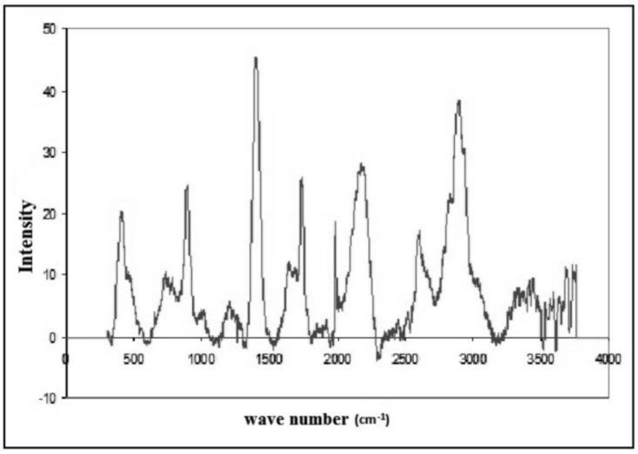


Figure 8.4 Raman spectrum of TPL/ZnS nanocomposite.

***CdS nanocrystal synthesis***

• CdS nanocrystals were synthesized through the reaction of zinc chloride with thiourea using Maleic anhydride–Octane-1–Vinylbutyl Ether terpolymer as the matrix.

• TEM images of the nanoparticles show that the sizes of these nanoparticles are below 5 nm.

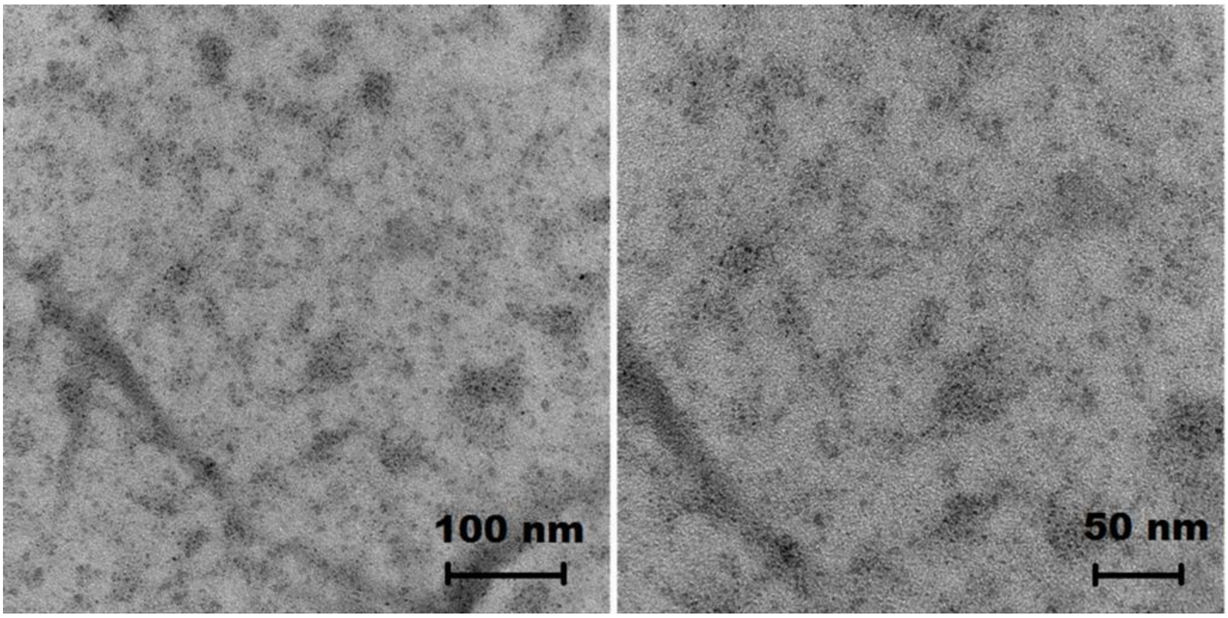


Figure 9.1 TEM images of TPL/CdS nanocomposite

• From the UV–visible results optical Band gap and mean value of the diameter of the CdS nanocrystals were deduced. Thus optical Band gap of the TPL/CdS nanocomposite was approximately 3.46 eV, and this result is higher than that of bulk material (2.42 eV). This shifting to the higher energy state is the evidence of the formation of CdS nanocrystals in TPL matrix. Besides mean value of the diameter of the CdS nanocrystal was found from the UV-visible results with Henglein equation. This average size was about 2.36 nm. The value of absorption for nanocomposite is 5.7 times more than the absorption value for terpolymer matrix.

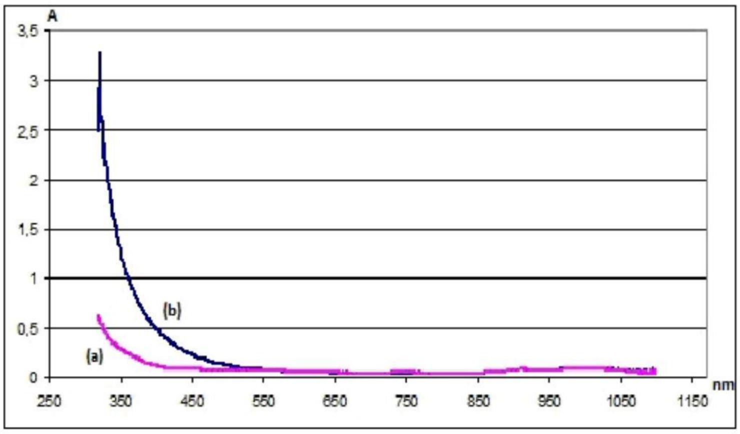

Figure 9.2 UV-visible absorption spectra of TPL (a) and TPL/CdS (b) nanocomposite

• Energy dispersive X-ray results show that synthesized sample consists of carbon, nitrogen, oxygen, sulfur, chlorine and zinc.

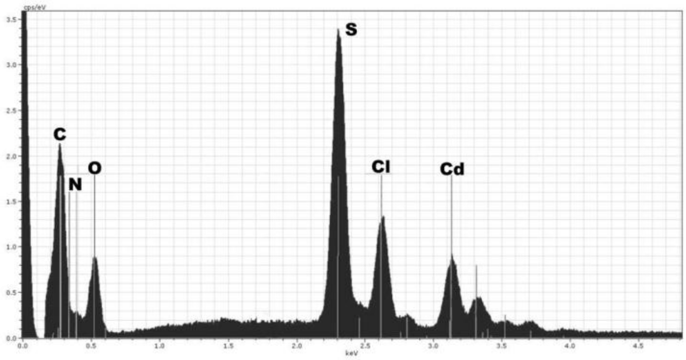


Figure 9.3 EDX spectrum of TPL/CdS nanocomposite.

• Raman spectrum shows characteristic peaks for ZnS in 350, 700, 1020 and 1406 $cm^{-1}$ wave numbers

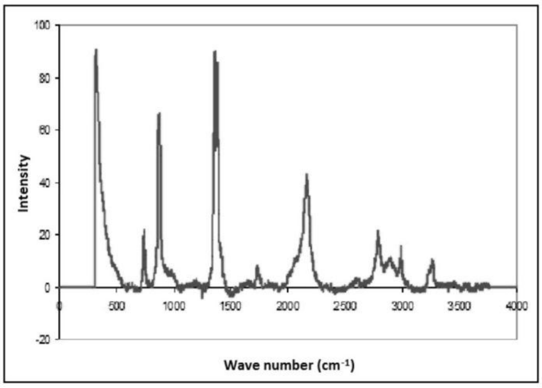


Figure 9.4 Raman spectrum of TPL/CdS nanocomposite.

***PVA-MWCNT synthesis***

• MWCNTs were synthesized via the chemical vapor deposition method using the Al-Fe-Co catalyst.

• Oxidized MWCNTs were easily reacted with PVA to form a grafted structure via the Fischer esterification reaction.

• FTIR spectrum shows strong characteristic peaks for C-O and C=O of the ester formed with Fischer esterification.

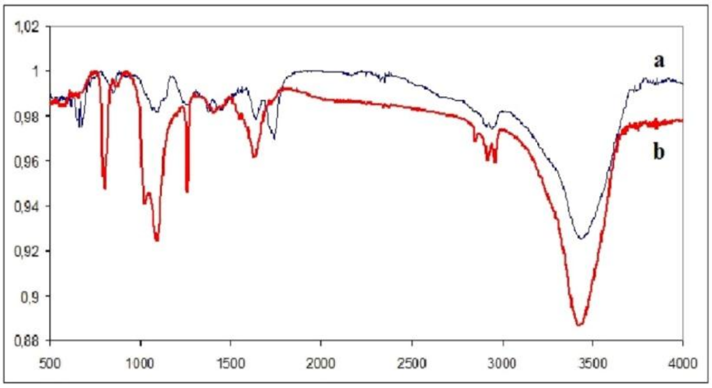


Figure 10.1 FTIR spectra of PVA (a) and PVA-MWCNT(b) nanocomposite.

• EDX spectroscopy results show the characteristic peaks for carbon and oxygen.

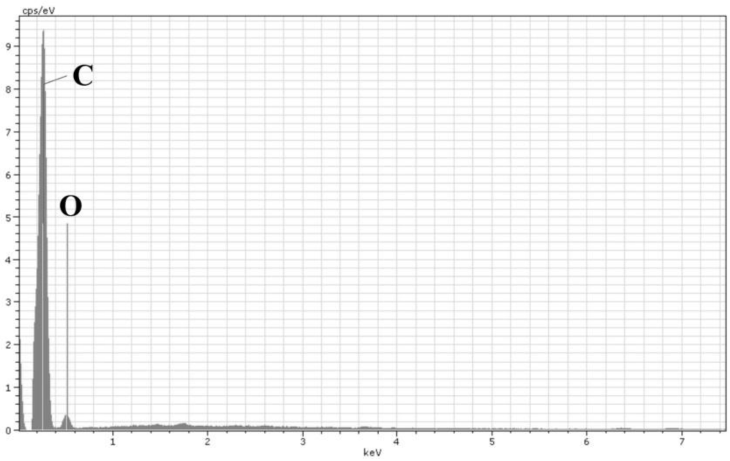


Figure 10.2 EDX spectra of PVA-MWCNT nanocomposite.

• 5.5 nm average coherence length was estimated from the XRD pattern by the Debye-Scherrer`s equation for PVA-grafted MWCNT.

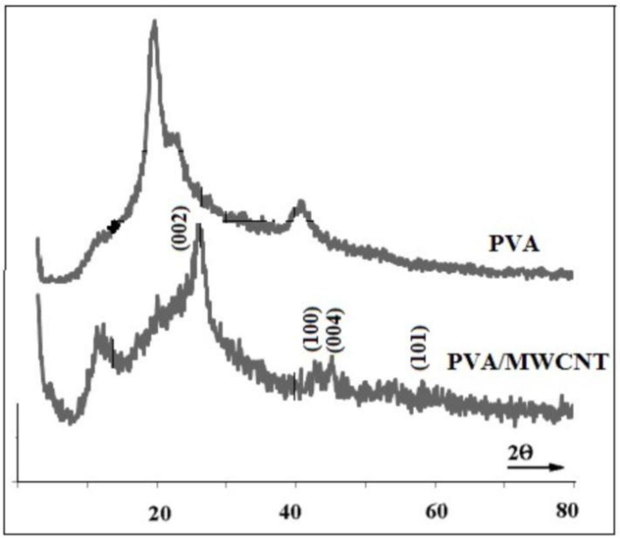


Figure 10.3 XRD spectra of PVA and PVA-MWCNT nanocomposite.

• TEM images of the pristine-MWCNT and PVA-grafted MWCNT differ with the shadow appeared on the surface of the MWCNT for grafted case which is the PVA cover.

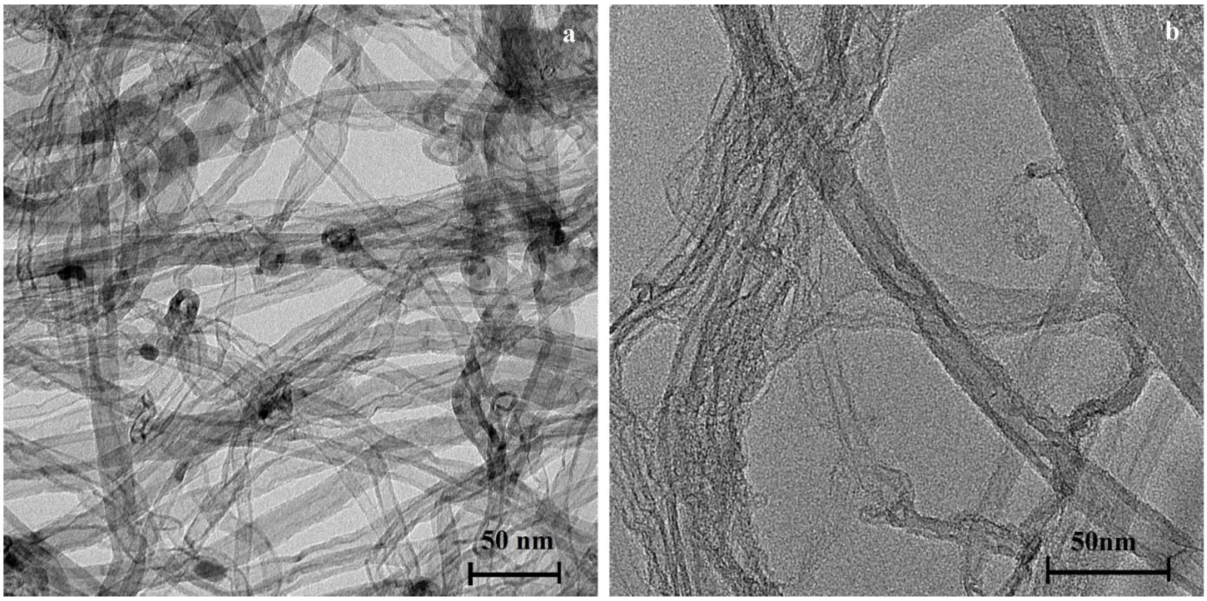


Figure 10.4 TEM images of pristine MWCNT (a) and PVA-grafted MWCNT (b)

**The potential impact**

The NAPEP project has successfully demonstrated the feasibility of mutually beneficial scientific collaboration between Azerbaijan and EU member states. The direct scientific output of the project can be summarized as follows:

- developments in the field of semiconductor quantum dot and luminescent phosphor research,
- developments in the synthesis, property tailoring and applications of various inorganic one-dimensional nanostructures,
- developments in the field of transparent conductive coatings,
- developments in the field of nanotechnology based photovoltaic solutions.

The whole project was realized in a continuous trilateral collaboration between all three partner universities. The established nanotechnology platform will strengthen the regional leadership position of Baku State University in the field, and simultaneously, it will improve the networking potential of the EU member state partners. Of particular importance are the personal contacts established during the project by partner scientists to key decision makers and industrial end users in all three countries. Last but not least, the cross-platform training offered to the young researchers of all three partners will undoubtely have a beneficial effect on the careers of these colleagues.

It is expected that the established trilater cooperation will continue by finding alternative financing sources after the conclusion of the NAPEP project. The following collaborational actions were already taken:

- Memorandum of Understanding of research partnership between BSU-Szeged and BSU-Oulu. These documents are ready and are in the process of official signature.
- ERASMUS partnerships established between BSU-Szeged and BSU-Oulu.
- One BSU researcher to pursue a PhD student career at Oulu.
- One BSU researcher to participate in a joint PhD training program at Szeged
- All three partners to participate in at least one joint proposal submitted to H2020 calls in 2014.

It is evident from the rich scientific output and live trilateral collaboration that the NAPEP project was able to accomplish its goals successfully. All three partners are highly satisfied with the project results and are 100% motivated to continue the joint research even by using their own alternative resources for this purpose.

- The address of the project public website, if applicable as well as relevant contact details.

www.napep.net Logo: napep

## 4.2 Use and dissemination of foreground

**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, STARTING WITH THE MOST IMPORTANT ONES**

| 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[27] (if available) | Is/Will open access[28] provided to this publication? |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Study on dielectric properties of CdS/PVA nanocomposites obtained by using successive ionic layer adsorption and reaction | M.B.Muradov, G.M.Eyvazova, K.A.Yusifova, R.K.Mammadov, A.Z.Salahova | World Journal of Condensed Matter Physics | Vol. 3,No 1, 2013 | *Office for Official Publications of the European Communities* | *Luxembourg* | 2013 | 5 | | yes/no |
| 2 | Synthesis of CuS and PbS nanocrystals on the basis of PE/NBR | N.O. Balayeva, O.O. Askerova , A. A. Azizov , | Composites Part | Vol. 53, Octobr 2013, | | | 2013 | p.391-394 | | |

[27] 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).
[28] 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.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | polymer/elastomeric composites for their applications | R. Alosmanov M.B.Muradov, G.M.Eyvazova | Engineering | | | | | | | |
| 3 | Photoelectrical properties of p-GaAs/n-$Cd_{1-x}Zn_xS_{1-y}Te_y$ heterojunctions | A.Sh.Abdinov, H.M.Mamedov, V.U.Mamedov | International J. of Engineer. and Sciences | (submitted) | | | | | | |
| 4 | Investigation of p-GaAs/n-$Cd_{1-x}Zn_xS_{1-y}Te_y$ heterojunctions deposi-ted by electrochemical Deposition | H.M.Mamedov, V.U.Mamedov | Journal of Optoelectronics and Advanced Materials | submitted | | | | | | |
| 5 | Preparation and investigation of P-GAAS/N-$Cd_{1-X}Zn_XS_{1-Y}Te_Y$ heterojunctions deposited by electro-chemical deposition | H.Mamedov, M.Muradov, A.Kukovecz, K.Kordas, D.Hashim, V.Mamedov | Solar Energy Materials and Solar Cells | submitted | | | | | | |
| 6 | Synthesis and characterization of CdS nanocrystals in Maleic Anhydride – Octene-1 – Vinylbutyl Ether terpolymer matrix | O.H.Akperov, M.B.Muradov, E.Y.Malikov, E.O.Akperov, A.M.Maharramov, G.M.Eyvazova, R.E.Mammadova, Á.Kukovecz, Z.Kónya, R.Puskás, D.Madarász, P.Pusztai | Iranian Polymer J/(Springer) | submitted | | Iranian | | | | |
| 7 | In situ synthesis of ZnS nanocrystals in previously formed | O.H.Akperov, M.B.Muradov, E.Y.Malikov, | Current Science | submitted | | Indian | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | template of Maleic Anhydride-Octene-1-Vinylbutyl ether terpolymer and its characterizations | A.M.Maharramov, E.O.Akperov, G.M.Eyvazova, Á.Kukovecz, Z.Kónya | | | | | | | | |
| 8 | Synthesis and characterization of the nanocomposite on the basis of Polyvinyl alcohol and multiwalled carbon nanotubes | E.Y.Malikov, M.B.Muradov, O.H.Akperov, G.M.Eyvazova, Á.Kukovecz, Z.Kónya, R.Puskás, D.Madarász, L.Nagy | Carbon | submitted | | | | | | |

| TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NO. | Type of activities[29] | Main leader | Title | Date/Period | Place | Type of audience[30] | Size of audience | Countries addressed |

[29] 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.

[30] 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).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | *Conference* Preparation and characterization of PE/NR-CuS, PbS, CdS, ZnS nanocomposites on the basis of nitrile rabber/polyethylene polymer composites | N.Balayeva | SIWAN 5 $5^{th}$ Szeged Int.Workshop on Advances inNanoscience | 24-27 october, 2012 | Szeged/Hungary | | | |
| 2 | Formation of the copper sulfide nanoparticles by ion exchange from electrolyte solutions | M.B.Muradov | SIWAN 5 $5^{th}$ Szeged Int.Workshop on Advances inNanoscience | 24-27 october, 2012 | Szeged/Hungary | | | |
| 3 | In situ synthesis of Ma-leic anhydride-Octene 1-Vinyl Butyl/CdS and Maleic anhydride-Octe-ne 1-Vinyl Butyl/ZnS nanocomposites and characterization with several investigation methods | E. Malikov | SIWAN 5 $5^{th}$ Szeged Int.Workshop on Advances inNanoscience | 24-27 october, 2012 | Szeged/Hungary | | | |
| 4 | Structure of nanocom-posites on the basis polypropylene and zirconium dioxide nanoparticles | F.V.Hajiyeva | SIWAN 5 $5^{th}$ Szeged Int.Workshop on Advances inNanoscience | 24-27 october, 2012 | Szeged/Hungary | | | |
| 5 | Synthesis and investigate of maleic anhydride-oktene- | Z.Q.Mamiyev | SIWAN 5 $5^{th}$ Szeged Int.Workshop | 24-27 october, 2012 | Szeged/Hungary | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1/CdS Nanoparticles | | on Advances inNanoscience | | | | | |
| 6 | Synthesis of copper sulfide nanoparticles by combined Successive Ionic Layer Adsorption and Reaction(SILAR) and ion exchange methods | M.B.Muradov | ICCE-21 Tenerife, 21st Annual Int. Conf. on Composites or Nano Engin. | July 21-27, 2013 | Canary Islands, Spain, (the “Hawaii” of Europe) | | | |
| 7 | In situ synthesis of CdS and ZnS nanocrystals in the template of Maleic anhydride- Octene- 1-VinylButyl ether terpolymer | E. Malikov | ICCE-21 Tenerife, 21st Annual Int. Conf. on Composites or Nano Engin. | July 21-27, 2013 | Canary Islands, Spain, (the “Hawaii” of Europe) | | | |
| 8 | Electronic properties of $TiO_2/Cd_{1-X}Zn_XS_{1-Y}\ Se_Y$/ Si nano-structured solar cells | H.Mamedov | ICCE-21 Tenerife, 21st Annual Int. Conf. on Composites or Nano Engin. | July 21-27, 2013 | Canary Islands, Spain, (the “Hawaii” of Europe) | | | |
| 9 | Selective methods formation of nanoparticles chalcogenide semiconductors | M.B.Muradov | | May 24- , 2011 | Finland-Oulu | | | |
| 10 | Oxidative chloro-phosphorylation | O.Balayeva | | May 24- , 2011 | Finland-Oulu | | | |
| 11 | Formation of CdS | A.Amrahova | | May 24- , 2011 | Finland-Oulu | | | |
| 12 | Oxidative chlorophosphorylation | R.Hajimammadov | | May 24- , 2011 | Finland-Oulu | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | Sorption of ions some heavy metals fromchloride solutions with phosphor – containing sorbent | A.Cavanshirova | | May 24- , 2011 | Finland-Oulu | | | |
| 14 | Spintronics New Tendency in Electronics | T.Ismayilov | | May 24- , 2011 | Finland-Oulu | | | |
| 15 | *Student seminar and project meeting* Thermal stability of metal nanoparticle decorated support materials | Anne-Riikka Leino | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |
| 16 | *Student seminar and project meeting* | **Niina Halonen** | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |
| 17 | *Student seminar and project meeting* | | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |
| 18 | *Student seminar and project meeting* | | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |
| 19 | *Student seminar and* | | NAPEP | 28 August – | Finland-Oulu | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *project meeting* | | project meeting, student seminar and workshop | 2 September 2012 | | | | |
| 20 | *Student seminar and project meeting* | | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |
| 21 | *Student seminar and project meeting* | | NAPEP project meeting, student seminar and workshop | 28 August – 2 September 2012 | Finland-Oulu | | | |

**Section B (Confidential[31] or public: confidential information to be marked clearly)**
**Part B1**

NAPEP was Coordination and support Action project. In Framework this project it was not  apllied for patent, trademark and others.

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

## 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:** | 266600 |
| **Title of Project:** | *Nanotecnology platform for electronics and* |
| **Name and Title of Coordinator:** | Dr.Mustafa Muradov |

## B Ethics

| | |
|---|---|
| **1. Did your project undergo an Ethics Review (and/or Screening)?**<br>• 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?<br>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 0No*** |
| **2. Please indicate whether your project involved any of the following issues (tick box) :** | ***YES*** |
| **RESEARCH ON HUMANS** | |
| • Did the project involve children? | NO |
| • Did the project involve patients? | NO |
| • Did the project involve persons not able to give consent? | NO |
| • Did the project involve adult healthy volunteers? | NO |
| • Did the project involve Human genetic material? | NO |
| • Did the project involve Human biological samples? | NO |
| • Did the project involve Human data collection? | NO |
| **RESEARCH ON HUMAN EMBRYO/FOETUS** | |
| • Did the project involve Human Embryos? | NO |
| • Did the project involve Human Foetal Tissue / Cells? | NO |
| • Did the project involve Human Embryonic Stem Cells (hESCs)? | NO |
| • Did the project on human Embryonic Stem Cells involve cells in culture? | NO |
| • Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos? | NO |
| **PRIVACY** | |
| • Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)? | NO |

| | |
|---|---|
| • Did the project involve tracking the location or observation of people? | |
| **RESEARCH ON ANIMALS** | NO |
| • 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** | NO |
| • 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 | 0 Yes 0 No |
| • 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 | | 3 |
| Work package leaders | 4 | 3 |
| Experienced researchers (i.e. PhD holders) | | |
| PhD Students | 5 | 4 |
| Other | 16 | 22 |

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

## D Gender Aspects

| | | |
|---|---|---|
| **5. Did you carry out specific Gender Equality Actions under the project?** | ○<br>○ | Yes<br>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 | ○ | ○ | ○ | ○ | ■ |

○ Other:

**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

○ 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)?**

■ Yes- please specify

○ No

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

■ Yes- please specify

○ No

## F Interdisciplinarity

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

■ Main discipline[32]:

○ Associated discipline[32]: ○ Associated discipline[32]:

## 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)* | ○<br>■ | Yes<br>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

[32] 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)?** | ○<br>○ | Yes<br>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<br>Audiovisual and Media<br>Budget<br>Competition<br>Consumers<br>Culture<br>Customs<br>Development Economic and Monetary Affairs<br>Education, Training, Youth<br>Employment and Social Affairs | | Energy<br>Enlargement<br>Enterprise<br>Environment<br>External Relations<br>External Trade<br>Fisheries and Maritime Affairs<br>Food Safety<br>Foreign and Security Policy<br>Fraud<br>Humanitarian aid | | Human rights<br>Information Society<br>Institutional affairs<br>Internal Market<br>Justice, freedom and security<br>Public Health<br>Regional Policy<br>Research and Innovation<br>Space<br>Taxation<br>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?** | **8** |
| **To how many of these is open access[33] provided?** | **2** |
| **How many of these are published in open access journals?** | **1** |
| **How many of these are published in open repositories?** | |
| **To how many of these is open access not provided?** | |
| **Please check all applicable reasons for not providing open access:** | |
| ❑ publisher's licensing agreement would not permit publishing in a repository<br>❑ no suitable repository available<br>❑ no suitable open access journal available<br>■ no funds available to publish in an open access journal<br>❑ lack of time and resources<br>❑ lack of information on open access<br>❑ other[34]: …………… | |

| | | |
|---|---|---|
| **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).* | | **NO** |
| **16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).** | Trademark | **NO** |
| | Registered design | **NO** |
| | Other | **NO** |
| **17. How many spin-off companies were created / are planned as a direct result of the project?** | | **NO** |
| ***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:**

| | |
|---|---|
| ❑ Increase in employment, or | ■ In small & medium-sized enterprises |
| ❑ Safeguard employment, or | ❑ 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:* |

33 Open Access is defined as free of charge access for anyone via Internet.
34 For instance: classification for security project.

| | |
|---|---|
| Difficult to estimate / not possible to quantify | ☐ |

## 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 ○ No

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

■ Yes ○ 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?**

| | | | |
|---|---|---|---|
| ■ | 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 | ■ | 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 | ■ | English |
| ☐ | Other language(s) | | |