Graphene research in Lithuania with subsequent application in bioanalysis, energy storage and optical materials

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Several research groups are active in the area of graphene, which are spread across Universities and Research Centers in Lithuania. They are working in close collaboration with each other as well as with national and European institutions to perform fundamental and applied research in graphene and related topics.

In *Vilnius University* graphene is under investigation within several different research groups. At the *Department of General & Inorganic Chemistry*, *Laboratory of Carbonaceous Materials* has been established since 1992. Research in this laboratory is focused on: **(i)** Synthesis of carbon nanostructures (grapene, graphene oxide, SWNT, MWNT, nanocones, nanopipettes, nanorods, etc.) from various precursors; **(ii)** Modification the surface of carbon nanostructures with functional groups; **(iii)** Preparation of membranes from the synthesized carbon nanostructures; **(iv)** Examination of the synthesized carbon nanostructures; **(v)** Application of synthesized carbons in nanoelectronics; fuel cells; energy storage; bionanotechnology, etc.; **(vi)** Building up mathematical models having an aim to optimize the synthesis conditions, construction of sensors and other parameters; **(vii)** Investigation of synergism in micro-disperse compositions including various forms of carbon [1 – 3]. Several different synthesis methods of graphene oxide as well as other pre-graphene phases are pursued in the *Laboratory of Carbonaceous Materials*. Product range includes both negative and positive charged particles with different functional groups. Graphene oxide and graphene membranes are prepared by using a modified protocol of filtration of water suspension; this protocol includes the elements of layer-by layer assembly. The thickness of membranes can reach several nm. At the same Department in the *Laboratory of Sol-Gel Chemistry* graphene, graphite oxide and SWCNTs are studied in the role of promising material for saturable absorbers in laser mode locking [4] because of the fast recovery time, which covers a broad spectral range in the near infrared, and excellent chemical stability. Currently, fabrication of polymer composites based on polymer matrix for saturable absorbers is very popular. But due to nature of organic polymer matrix, these composites are unstable on higher temperatures or in high energy light expositions. Therefore a sol-gel process for the fabrication for inorganic (i.e. silica) or semi-organic (organic-modified silica) matrix can be a promising way to produce photo-chemically and thermally stable composites: thin/thick coatings, glasses and ceramics.

Another research group from *Vilnius University* working with graphene is set up at the *Institute of Biochemisty, Department of Bioanalysis*. Main research activity at this department is design of

biosensors and bioanalytical systems and investigation of electron transport in the system electrode-enzyme. Carbon nanotubes and graphene-related materials are successfully used as electrode materials [4]. Using these materials *Department of Bioanalysis* focused their activity on creation of biosensors and biosensor arrays for the determination of physiologically important metabolites like glucose, ethanol, cholesterol, heavy metals, inhibitors, etc. Biosensor based analytical systems have been developed and implemented into medicine food quality control. At the present time research are focused mainly on **(i)** Creation of reagentless screen-printed biosensors and biosensor arrays; **(ii)** Creation of analytical systems for on line monitoring of biologically active compounds in food-stuffs and environment. To reach those objectives both modified graphene and carbon nanotubes are used as enzyme supports and electrode materials. Research is performed in tight collaboration with Italian, Swedish and German research centers on the basis of joint projects.

Center fo Physical Sciences and Technology includes a few groups working in different departments that are involved in research and technology development by using graphene.

Department of Nanoengineering in Center for Physical Sciences and Technology was established just in 2011. The mission of the Department is development of new nanoscale materials, structures and processes for life science, medicine and analytical applications. Graphene and/or graphene oxide is used to develop sensors and biosensors employing nanostructured materials. Role of graphene nanostructures in such sensors is to enhance an electrochemical signal as (bio)sensor response to an analyte. Project funded by the European Social Fund under the Global Grant measure, Project No. VP1-3.1-ŠMM-07-K-01-124, “Nano- and Lasertechnology Application to the Investigation and Modification of Graphene and to the Development and Miniaturisation of (Bio)Sensors for Food Quality Control” is carried out in this Department, and it is based on graphene researches and application to miniaturised (bio)sensors. For this purpose, graphene is functionalised to improve its immobilisation ability on an electrode surface and affinity to biologically labile molecules. Further, immobilised graphene is characterised applying optical and electrochemical methods. Reproducibility investigations of such nanostructure formations has a great importance in these researches. The optimised protocols for graphene nanostructure formation will be applied to miniaturisation of electrochemical (bio)sensing devices.

Activities at *Department of Laser Technologies* cover localized reduction of graphite oxide to graphene by laser irradiation, formation of heat and electro-conducting circuits [4] as well as modification and structuring deposited graphene layers for sensors.

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