"Recent progress in chemistry of nanomaterials: applications in electronics, energy conversion and biosciences"

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(10x3 hours = 30 hours, winter semester 2017/2018)

Recent progress in chemistry has led to new materials of unmatched and difficult to predict properties. The role of modern functional materials in emerging technologies is constantly growing. Among them carbon, organic electroactive nanomaterials as well as semiconductor and metal nanocrystals, to which this course is devoted, deserve a special interest.

The course will start with the discussion of graphite intercalation compounds with special emphasis on their structural and electronic properties. This will constitute the basis for the description of graphene, its physical properties and methods of its functionalization. In the next part the preparation methods yielding single and multiwall carbon nanotubes will be outlined and the relation between chirality indices and electronic properties of nanotubes will be discussed. This will be followed by a systematic description of the nanotubes' functionalization. Selected examples of graphene and nanotubes applications in electronic devices and in biosciences will complete this part of the course (8 hours).

The second part of the course will be devoted to low and high molecular weight organic semiconductors and metals. Principles of their design will be discussed and methods of their synthesis will be critically reviewed. The determination of their ionization potential (IP) and electron affinity (EA) by electrochemical methods and photoelectron spectroscopy will be discussed in detailed since these parameters play a predictive role in selecting suitable candidates for applications in electronics. This will be followed by the description of the principles of spectroelectrochemical (UV-vis-NIR, Raman, EPR) investigations and the discussion of their role in profound characterization of electroactive organic compounds. In the next part principles of scanning tunneling microscopy (STM) will be briefly discussed and its application to the studies of self-assembling phenomena in monolayers of organic semiconductors will be outlined. Then the critical review of the thin organic layers deposition methods will be presented in relation to the resulting supramolecular organization. Finally, instructive examples of the application of organic semiconductors and organic metals in such electronic devices as field effect transistors, light emitting diodes, photodiodes, photovoltaic cells and biosensors will be demonstrated (10 hours).

The third part of the course of the lecture will focus on the preparation of binary, ternary and quaternary semiconductor nanocrystals with special emphasis on newly developed nanocrystals of low band gap semiconductors which do not contain toxic elements. This will be followed by detailed description of their surface functionalization in view of their application in quantum dots-based light emitting diodes (QD-LEDs), quantum dots-based photovoltaic cells (QD-PCs) and in biological imaging. Different methods of the preparation of semiconductor nanocrystals-organic semiconductors hybrids will then be discussed with special emphasis on the methods involving: i) surfacial ligands exchange; ii) grafting using specially designed linker ligands; iii) molecular recognition. Description of promising applications of these hybrid-type materials in optoeelectronics, energy conversion and bio-imaging will complete this part of the course (6 hours)

In the last part of the lecture, different aspects of the preparation and functionalization of metal nanocrystals will be outlined. This will be completed by the demonstration of their peculiar optical properties and their application as substrates in *surface enhanced Raman spectroscopy* (*SERS*). Selected examples of their application in catalysis, bio-sensing and photothermal therapy will be given (6 hours).

About the lecturer

Adam Proń was born (1951) and educated in Poland. After obtaining his MSc in chemistry he moved to the USA where in 1980 he completed his PhD at the University of Pennsylvania (under the supervision of Alan G. MacDiarmid - Nobel Prize winner in chemistry in 2000). Then he joined Warsaw University of Technology where he became full professor in 1993. In the period of 1991-1993 he shared his time between Poland and the USA where he worked in Uniax Corporation in Santa Barbara, California, closely collaborating with Alan J. Heeger - another Nobel Prize winner of 2000. In 1998 he moved to Atomic Energy Commission (CEA) in Grenoble (France) as director of research (directeur des recherches). In 2012 he retired from CEA (still keeping his connection with this institution as research advisor) and accepted full-time professorship at Warsaw University of Technology. In 2002 he got the prize of the Foundation for Polish Science considered the most prestigious scientific award in Poland. Profesor Proń is editor of "Synthetic Metals" - an Elsevier journal devoted to the chemistry, physics and engineering of carbon and organic electroactive materials *i.e.* the research domain covered in the proposed course. He published over 300 paper in such journals as "Journal of the American Chemical Society", "Advanced Materials", "Advanced Functional Materials", "Nano Letters", "Chemistry of Materials", "Macromolecules", "Physical Review Letters" and

others. He also holds several international patents. In addition to attracting governmental research funds he also succeeded in obtaining several purely industrial grants from such companies as Hitachi, Hutchinson, Electrorecherche and others.