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Laboratory: Flerov Laboratory for Nuclear Reactions, sector 8

Theme: 04-5-1131-2017/2021: Radiation Physics, Radiochemistry, and Nanotechnology Investigations Using Beams of Accelerated Heavy Ions

Project name: "Swift heavy-ion irradiation effects in carbon nanostructures"

Because of their unique physical and electrical properties, carbon nanomaterials are attractive candidates for use in next-generation nanosensors and nanodevices. Possible applicability of such nanocarbon-based devices under extreme environmental and operational conditions in many areas, including aerospace, nuclear reactors, and fuel storage devices, requires understanding of the irradiation effects occurring in such materials. The possibility of introducing a definite amount of low-dimensional defects into the system as well as a variety of irradiation inducing phenomena (e.g., cutting, welding, binding, coalescence, and localized defunctionalization) are other important aspects that are driving increased scientific attention.

Based on the above considerations, the aim of the present project is to investigate the effects induced in carbon nanomaterials by irradiation with swift heavy ions (SHIs), i.e., ions with kinetic energies E > 1 MeV/n. Given the ability of SHIs to displace large amounts of energy along a small cylindrical volume surrounding an ion trajectory, a highly localized structural modification inside so-called 'tracks', is possible for a variety of materials. In this project, we intend to employ this unique feature of SHI irradiation to create nanometer-sized modified regions in various carbon nanomaterials.

The project aim will be achieved by preparing the thin-film samples of selected carbon nanomaterials, performing the ion irradiations, and characterizing the samples by Raman and XPS spectroscopy. On the basis of the obtained data the relation between radiation dose and the extent and type of defects introduced in the material will be derived.

Project description:

1. Getting familiar with sample irradiation facilities at the IC-100 and U-400 cyclotrons, the XPS spectrometer and the integrated AFM Raman Confocal SNOM/NSOM system - principles of operation, basic theory on interaction of swift heavy ions with matter and Raman scattering. A series of excursions to the main experimental facilities at FLNR will be organized (microtron MT-25, cyclotrons: IC-100 and U400M).

2. Sample preparation – preparation of dispersions of carbon nanomaterials, deposition on porous membranes using the filtration and/or spin-coating method; optimization of the process parameters, impact of the sample preparation parameters on the structure and quality of deposited thin films.

3. Performing Raman spectroscopy measurements on virgin and ion beam (Xe 167 MeV) irradiated nanocarbon specimens. Highly oriented pyrolytic graphite (HOPG) will be use for comparison.

4. Performing XPS measurements on the prepared samples.

5. Results analysis – reasoning on the nature of vibrational spectrum of nanocarbons, the principles of Raman spectra analysis, including the analysis of the intensity ratios or band shape, spectral deconvolution, the relation between the structure and spectral shape.

Requirements:

The project is addressed to students and PhD students interested in radiation physics/chemistry and nanotechnology. Basic knowledge in the fields of nanotechnology and radiation physics that could be directly applied to understanding the irradiation effects is welcomed but not mandatory.

The maximum number of students is limited to 2.