Ion beam modification of graphene based materials and novel polymers for flexible electronics, sensorics and bio-application*

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Ion beam irradiation is a strong tool for intentional defect engineering in solid matter. When studying the formation of structural defects under ion irradiation, one should distinguish between two main mechanisms, determined by the method of energy transfer from an incident ion to lattice atoms: nuclear and electronic. If the transferred energy exceeds a certain threshold energy, then the atom may be permanently removed from the lattice, which leads to the formation of a defect. The electronic mechanism of energy transfer is determined by the inelastic interaction of the incident ion with the lattice electrons both free and localized [1, 2]. Various processes facilitate this mechanism: the generation of phonons due to the electron-phonon interaction, collective electronic excitations, and local ionization. Graphene oxide and polymers (such as PI) have aroused significant interest for supercapacitors and ultrasensitive gas detectors because of their remarkably high carrier mobility, extraordinary surface area, 2D structure and cost-effective easy-to-prepare nanoscale morphologies. Graphene oxide (GO), a 2D graphene precursor, is decorated with epoxides and hydroxyls on basal planes and carbonyls and carboxyls on the edges, which increase the hydrophilicity of GO and consequently enhance its sensitivity to water molecules [2, 3, 4].

This research line is strongly connected to the applications for a reliable power source with miniaturized sizes, miniaturized sensors of gasses, biological molecules, chemical molecules in general. A feasible solution could be the fabrication of micro-capacitors able to store and use energy, to respond to external stimuli as voltage, temperature, light and electrochemical reduction and oxidation processes, detection of adhered chemical and biological molecules in general and last but not least degradation of pollutants via photocatalysis. We will present our recent results of ion implantation of metal ions (Cu) of medium energies, ion lithography technique by C microbeam with 5 MeV energy for microdevice creation and electronic structure modification in various carbon-based surfaces. We received high-quality microstructures and surfaces with enhanced photocatalytic activity in GO and PI as well as functional humidity microsensors.

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* The research has been carried out at the CANAM (Centre of Accelerators and Nuclear Analytical Methods) infrastructure LM 2015056. The authors acknowledge the assistance provided by the Advanced Multiscale Materials for Key Enabling Technologies project, supported by the Ministry of Education, Youth, and Sports of the Czech Republic. Project No. CZ.02.01.01/00/22_008/0004558, Co-funded by the European Union. The implantations were carried out at IBC at the Helmholtz-Zentrum Dresden - Rossendorf e. V., a member of the Helmholtz Association.

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Accelerator mass spectrometry for tracing fossil content of combusted fuel

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Modern waste management is partly based on combustion of waste to the energy. As the European Union anticipates including municipal waste incineration installations in the EU Emission Trading Scheme [1], there will be a need for monitoring the fossil CO_2 emission inventory from incineration. Therefore, a reliable method is required for determining the fractions of bio- and fossil-based fuels in combustion facility. A straightforward method is to measure the fraction of radioactive ^{14}C in the CO_2 emissions, sampled directly from the stack of the combustion facility [2]. In practise the ^{14}C content can be measured with high precision by using accelerator mass spectrometry (AMS).

University of Helsinki and VTT Technical Research Centre of Finland have performed studies on sampling and measuring biofraction of CO_2 emissions from combustion. The first set of experiments was performed in early 2000's when exhaust gas samples gathered directly from power plants using different fuel mixtures were analysed [3]. This was followed by numerous collaborative projects between VTT and UH in which weekly and monthly samplings were developed based on hydroxide-based material and parallel technical development towards zeolite-based material [4].

In this work, a set of samples were obtained by burning fossil coal and carbonate as well as biobased pine-wood chips and caustic lime mud. The combustion of coal and wood chips was performed in a bench-scale test facility where the combustion conditions emulated those prevailing in a real power plant. The fossil carbonate and biobased lime mud were combusted in an electrically heated rotary kiln where no oxygen was added in the burning process. Samples of the exhaust gases were taken in both Tedlar gas sampling bags and flow-through steel containers. CO_2 was separated from the other exhaust gases (CO, SO_2 and CH_4) and water by freezing and releasing the CO_2 in suitable temperatures. The ^{14}C content of the purified CO_2 was measured in AMS either directly as a gaseous CO_2 sample or after graphitizing into a solid carbon sample. The results of different gas exhaust sampling methods as well as different sample introduction methods to the AMS system were compared and were in accordance with each other. The results confirm that by using a relatively simple sampling process connected to AMS, result in feasible, reproducible, and accurate ISO13833-compliant [2] method for analysing biofraction of combusted fuels.

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Elemental analysis of selected wines by Particle Induced X-ray Emission (PIXE) for determination of geographical origin*

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Varietal wines have become well-known worldwide for their extraordinary quality and taste. There are many wine producers around the world with the identified declaration of origin and protected process of wine production. Multi-element methods and statistical tools are used in this study to characterise the geographical authenticity of selected wine, as well as to verify compliance with the elemental concentration limits set by international authorities and national legislation. The analysis focused on 21 wine samples originating from 5 countries spanning 4 continents, while the Slovak wines were sourced from three renowned vineyard regions, featuring prominent varieties such as Chardonnay (white wine) and Blaufränkisch (red wine). For each foreign wine from Australia (Sauvignon Blanc), Argentina (Cabernet Sauvignon), New Zealand (Sauvignon Blanc) and South Africa (Chenin Blanc) — 3 samples from identical terroir areas, vintages and grape varieties were selected.

From each wine, a sample of 250 ml was taken for analysis. In addition, yttrium was introduced as an internal standard to calculate concentrations of elements of interest. Initially, the liquid wine samples were evaporated near dryness on a heating plate at 80°C. The residual was incinerated in an oven at 650°C for 15 hours. The resulting ashed substance was then pulverised and compressed into pellets for PIXE analysis.

Measurements were meticulously conducted at the Centre for Nuclear and Accelerator Technologies (CENTA), employing a 3 MV tandem accelerator manufactured by National Electrostatic Corp. (USA). Proton beams of 3 MeV were utilized for precise analysis employing the PIXE technique to determine the presence of 17 elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Mn, Fe, Cu, Zn, Br, Rb, Sr, and Ba). Several liquid samples were also measured by ICP-MS (Inductively Coupled Plasma Mass Spectrometry) to determine trace elements and to validate the solid sample preparation method (Li, B, Ti, V, Cr, Co, Ni, Mo, Cs, Ba), which required the development of a method for preparation of liquid samples from organic material. A comparison of concentrations obtained from PIXE and ICP-MS, followed by validation of declared origin using Linear Discriminant Analysis (LDA) was carried out to validate the origin of analysed wine samples. Using LDA with obtained elemental composition, wines originating from 4 regions were clearly identified.

* The authors acknowledge the support provided by the Slovak Research and Development Agency (project no. APVV-21-0059)

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Ion Beam irradiation and implantation for Novel Materials Research at Surrey Ion Beam Centre

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The UK National Ion Beam Centre is a national research facility supported by UKRI/EPSRC, providing ion beam services for researchers based both in UK and overseas, with laboratories located at Universities of Huddersfield, Manchester and Surrey.

At Surrey, surface modification of materials has been one of our major research areas since 1960s, such as ion implantation and analysis for semiconductors. More recently, activities on ion irradiation and analysis of other materials like ceramic superconductors and solid-state electrolytes (SSEs) are on the way up. In this presentation I will describe our recent collaborative research on in-situ He ion irradiation of ReBCO conductors, Xe ion irradiation for suppressing Li dendrite growth and smart cut for preparing semiconductor thin films for photonics applications.

Measurements of gamma-ray production cross-sections obtained by inelastic proton scattering on ^{40}Ca *

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Calcium is a common constituent of environmental, geological, cultural heritage, biological (bones) [1], and biomaterial samples. By measuring the inelastic proton cross-sections at energies higher than 3 MeV, a better calcium sensitivity in those materials could be obtained by IBA (Ion Beam Analysis) methods such as PIGE (Particle-Induced Gamma Emission). For standard-less calcium PIGE quantitation at higher energy than 4MeV, it is essential to have on one side reliable gamma-ray cross-sections and, on the other side a computer code capable of calculating calcium depth profiles from PIGE spectra (not only by X-ray measurements). In this purpose, the V. Manteigas has recently developed a computer code for standardless depth profiling from PIGE spectra [2].

The paper aims to report the differential and angle-integrated gamma-ray cross-sections obtained by inelastic proton scattering on ^{40}Ca isotopes for the most intense transitions of ^{40}Ca. The chosen proton energy range was between 4-12 MeV. The results were compared with theoretical calculations performed using the TALYS 1.9 code [3].

The measurements have been done in Bucharest, at a 9-MV Tandem Accelerator of IFIN-HH by using a CaF2/Ta target. The experimental setup consists of two HPGe detectors with 100% relative efficiency, placed at 110^{o} and 150^{o} relative to the beam direction. The chosen angles allow the extraction of angle-integrated cross-sections. For data normalization, a Faraday cup was employed. [3].

^{40}Ca is a doubly-magic nucleus, its first excited state has a very high energy: 3352.6 keV. Unfortunately, this level decays through a converted E0 transition, which is impossible to detect with our HPGe-based setup. The next transition (3736.5 keV) decays from a 3^- strong collective state and hence it is expected to collect a major part of the inelastic strength. The third transition has an energy of 3903.9 keV and decays from a 2^+ state which is also collective, part of the ground state rotational band. The detection of these two transitions with very good statistics was the main purpose.

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Ion cooler assisted ^{90}Sr measurements at CologneAMS

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Ion Laser InterAction Mass Spectrometry (ILIAMS) has demonstrated an extraordinarily high isobar suppression capability for a variety of radionuclides which are important for environmental research. For the detection of trace amounts of radionuclides selective laser photodetachment of the interfering isobars is used. This method requires the deceleration of the ion beam in a gas-filled radio-frequency quadrupole (RFQ) ion cooler. The admixture of O2 gas (≈3%) to the helium buffer gas has revealed a high isobar suppression, larger than 10^5 in the case of ^{90}Sr/^{90}Zr, at the Vienna Environmental Research Accelerator (VERA), even without the use of a laser.

Therefore, we have developed a unique low-energy isobar suppression unit at CologneAMS, the Anion Laser Isobar Separator (ALIS). It marks a significant extension to the CologneAMS infrastructure and will highly increase the number of available isotopes for Accelerator Mass Spectrometry (AMS). Many of those isotopes were inaccessible for AMS prior to the development of isobar suppression via lasers.

In this presentation we will report on our first successful tests of the advanced gas-filled RFQ ion cooler at the Vienna test bench, and will give insights from first benchmark tests conducted at ALIS in Cologne. Currently, approximately 30% transmission through the ion cooler can be achieved. Ion residence time measurements were performed to show that the new hybrid guiding electrode structure is working as intended. In the next phase the suitability for a high sample throughput will be tested and optimized. One goal is to establish our technique for AMS measurements of soil samples with low concentrations of ^{90}Sr, an environmental isotope of concern for humans due to its long biological half-life and high mobility in nature.