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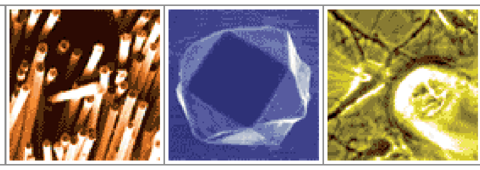

Università di Torino

NIS Colloquium

Material Analysis and Modification by Ion Beams

Monday, December 22th, 2008

Aula Franzinetti, comprensorio di Fisica, , Via Pietro Giuria 1, Torino

PROGRAMME

9.00 – 9.20	**Colloquium opening:** **Claudio Manfredotti** – NIS Università di Torino **Ettore Vittone** – NIS Università di Torino
9.20 – 10.00	**Iva Bogdanović Radović** Laboratory for Ion Beam Interactions, Ruđer Bošković Institute, Zagreb, - CROATIA *Materials analysis and modification using MeV heavy ions*
10.00 – 10.40	**Massimo Chiari** National Institute for Nuclear Physics (INFN), Florence - ITALY *Applied nuclear techniques for atmospheric aerosol studies*
10.40 – 11.10	**Break**
11.10 – 11.50	**Paolo Rossi** Sandia National Laboratories, Albuquerque, NM, USA Department of Physics of the University and INFN, Padua, ITALY *Advances of the "Cyclotron" Ion Photon Emission Microscope*
11.50 – 12.30	**Paolo Olivero** NIS Università di Torino and INFN - ITALY *A novel MeV ion implantation strategy for the direct fabrication of three-dimensional buried conductive channels in diamond*
12.30 – 14.00	**Lunch**
14.00 – 14.40	**Marco Bianconi** Institute for Microelectronics and Microsystems –CNR, Bologna - ITALY *Ion Beam Modification of Optical Materials*
14.40 – 15.20	**David N. Jamieson** ARC Centre of Excellence for Quantum Computer Technology, School of Physics, University of Melbourne - AUSTRALIA *Top-down pathways to devices with few and single atoms placed to sub-20 nm precision for quantum information processing technologies*.
15.20 – 16.00	***Closing remarks***

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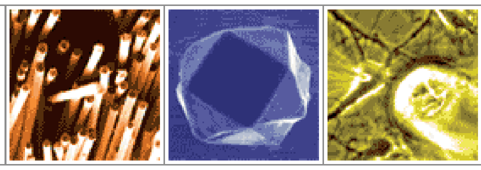

Materials analysis and modification using MeV heavy ions

Iva Bogdanović Radović[♦], Milko Jakšić, Marko Karlušić, Zdravko Siketić, Natko Skukan
Laboratory for Ion Beam Interactions, Ruđer Bošković Institute, Zagreb, Croatia

A review of recently applied ion beam analysis (IBA) techniques for materials analysis and modification using MeV heavy ions from ion accelerators in Zagreb will be presented.

Among the analysis techniques, the most widely applicable is certainly Time-of-flight Elastic Recoil Detection Analysis (TOF ERDA). In TOF ERDA heavy ions are used to recoil lighter atoms from the target. With this method all lighter elements present in the sample can be simultaneously measured and depth profiled with nm depth resolution. Slightly different detection system is used in Ion Induced Electron Emission ERDA that is installed at the microprobe beam line. This small and compact spectrometer is applied mainly for hydrogen imaging and depth profiling.

Another recently applied analysis technique is elastic scattering coincidence developed for three dimensional profiling of light elements in thin transmission targets. In this technique, recoiled atoms together with incident ions scattered from the target are detected in coincidence using particle detectors placed symmetrically around the beam direction at 45°. Three-dimensional imaging of low amounts of carbon in Al will be demonstrated.

Among the materials modification techniques that have been applied with heavy ion beams, creation of nm sized ion tracks in PMMA and $SrTiO_3$, as well as our studies of implantation conditions for diamond nanocrystal formation in amorphous silica, will be presented.

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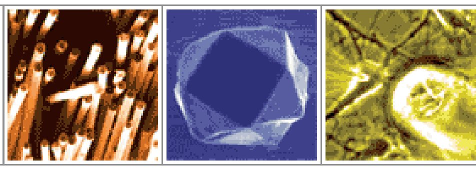

Applied nuclear techniques for atmospheric aerosol studies

Massimo Chiari♦
National Institute for Nuclear Physics (INFN), Florence, Italy

Ion Beam Analysis (IBA) techniques are a powerful tool to study atmospheric aerosol composition, since they are quantitative, multi-elemental, fast, high-sensitivity and non-destructive analytical methods.

At the 3 MV Tandetron accelerator of the LABEC laboratory of INFN in Florence an external beam facility is fully dedicated to measurements of elemental composition of atmospheric aerosols. All the elements with Z>10 are simultaneously detectable by Particle Induced X-ray Emission (PIXE) in few minutes of beam time, including several important tracers of peculiar aerosol sources and potentially harmful elements, with minimum detection limits ranging between 1 and 10 ng/m^3. Light elements (H, C, N, O), which are the main aerosol constituents, can be detected by means of in-vacuum Particle Elastic Scattering Analysis (PESA). The application of both PIXE and PESA allows a complete mass reconstruction of aerosol samples.

Since these methods are non-destructive, it is possible to apply complementary techniques, like Ion Chromatography and Thermal Optical Transmittance analysis, to the same samples, obtaining information, for example, on the chemical composition.

Scanning possibility may also be very useful, allowing time trend reconstruction by the analysis of time-sequence aerosol deposits collected by continuous samplers. Using a two-stage *streaker* sampler the concentration time series of all the elements with Z>10 can be measured with hourly resolution.

In this talk the peculiarity of these methods will be highlighted and the results of recent campaigns will be shown, including the application of IBA and complementary techniques to aerosol daily and hourly samples, collected in urban and remote areas.

Moreover, new results on ^{14}C analysis with Accelerator Mass Spectrometry (AMS) measurements on the aerosol carbonaceous fraction to discriminate between fossil fuels and other sources (biogenic emissions and biomass burning) contribution will be presented.

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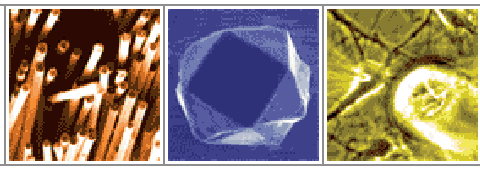

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Advances of the "Cyclotron" Ion Photon Emission Microscope

Paolo Rossi♦
*Sandia National Laboratories, Albuquerque, NM, USA**
Department of Physics of the University and INFN, Padua, Italy

Radiation Effects Microscopy for the Single Event Effect (SEE) assessment of the next generation integrated circuits will require ions of GeV energies, provided by a few cyclotrons in the world. Since such ions are so hard to focus, the Ion Beam Analysis group at Sandia proposed the Ion-Photon Emission Microscope (IPEM) that allows broad beams and determines the position of every single ion. This is achieved through an optical microscope that measures the light spot produced when the ion crosses a thin luminescent foil placed on the sample surface.

Available organic-phosphor foils require a large thickness to generate enough photons and this brings to poor spatial resolution. To solve this problem, we have "MOCVD" grown thin, self-supporting, n doped GaN films that are extremely bright. Unfortunately the long light decay time of doped GaN, although acceptable for SEE, does not allow other "fast" applications. To improve the time resolution, we have developed submicron InGaN-GaN "multiple quantum well" foils, derived from a structure already invented at Sandia for blue LEDs.

We have recently installed an updated IPEM on one of the Sandia ion microprobe lines to demonstrate the principle and prove its potential as a portable radiation effects microscope that can be subsequently moved to the LBNL GeV cyclotron facility. Performance of phosphors materials and overall system is detailed.

* Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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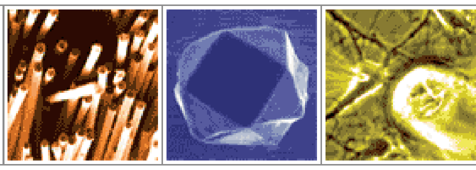

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A novel MeV ion implantation strategy for the direct fabrication of three-dimensional buried conductive channels in diamond

Paolo Olivero♦
Centre of Excellence "Nanostructured Interfaces and Surfaces", University of Torino
Experimental Physics Department, INFN sez. Torino, University of Torino

The process of ion-induced graphitization in diamond has been studied since the 70s [1]. In particular, the electrical conduction mechanisms involved in the transition from the insulating diamond structure to a conductive graphitic phase have been investigated in detail [2-6]. With only few exceptions [7-9], the vast majority of previous works were performed at relatively low energies (20-320 keV), determining the formation of superficial graphitic paths. Apart from fundamental studies, the formation of conductive channels has found interesting technological applications ranging from integrated IR emitters [10] and bolometers [11] to contacts for field emitters [12].

In the present work we report on a novel method for the fabrication of three-dimensional buried graphitic micropaths in single crystal diamond with the employment of focused MeV ions.

The use of implantation masks with graded thickness at the micrometer scale allows the formation of conductive channels which are embedded in the insulating matrix at controllable depths. In particular, the modulation of the channels depth allows the surface contacting of the channel terminations without further fabrication stages. Channels implanted with different sizes and ion fluences were characterized with IV measurements at different stages of the sample processing (annealing temperature and time). Scanning probe and optical profilometry were employed to study the swelling effects associated with ion-induced damage.

The application of buried conductive channels in diamond to devices of technological interest will be discussed.

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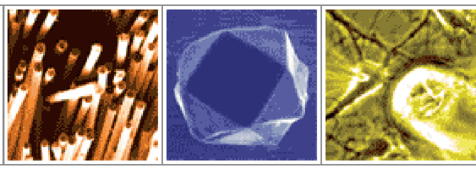

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Ion Beam Modification of Optical Materials

Marco Bianconi♦
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The study of the interaction of ions with inorganic insulators presents unsolved and challenging problems. The mechanisms responsible for the generation of damage in the electronic energy loss regime are not fully understood and, moreover, the characterization of the defects in this class of materials is rather complex. For these reasons, in spite of the relevant studies performed so far, this is still a fundamental matter of investigation. From the applicative point of view there is evidence and documentation of a wide number of macroscopic properties that can be modified and controlled by a suitable choice of the irradiation parameters (energy, fluence, temperature). The unique and reliable characteristics of the ion implantation processes, associated with the conventional planar technologies developed for the Silicon microelectronics, has opened new perspectives in the fabrication of integrated optics, micro-devices and photonic crystals.
This lecture will cover the following topics:

- Interaction of ions with insulators
- Mechanisms of defect formation in insulators
- Analysis of defects, with particular emphasis on RBS-channeling
- Defect engineering
- Modification of the optical properties and waveguides formation
- Modification of the chemical properties and micromachining
- Examples of integrated optical and photonic devices produced by ion implantation
- Applications and limits of the ion implantation in the nanotechnology

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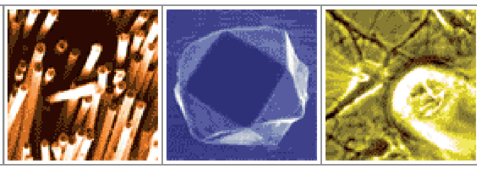

Top-down pathways to devices with few and single atoms placed to sub-20 nm precision for quantum information processing technologies.

David N. Jamieson♦
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Over the past decade numerous proposals have emerged for revolutionary new devices that exploit fundamental quantum mechanical principles to store and process information. Quantum computers use single quantum particles to store information as superimposed quantum states based on charge or spin. These computers can solve problems that would be difficult or impossible on classical computers. The construction of these devices presents formidable technical challenges owing to the requirement to control and readout single quantum states typically encoded on single atoms. Solid state devices present special challenges because the very demanding requirements for the perfection of the materials and the required fabrication precision. For example, the Kane quantum computer based on spin, devices based on charge and other proposals to exploit the NV^- colour centre in diamond require the positioning of single atoms with a sub-20 nm precision. In the case of diamond, we have developed a novel ion beam lithography method that allows for the machining of micro and nanostructures in diamond substrates. The method uses a combination of MeV nuclear microprobe and keV Focused Ion Beam irradiation. We have used this technique to fabricate diamond devices containing NV^- colour centres that display optical antibunching combined with nanostructures that, with further development, have the potential to display novel useful optical properties. In the case of silicon our approach is to implant single atoms through electron beam lithographically defined surface masks and detect the electron-hole pairs created in the substrate as the ion dissipates its kinetic energy. To date we have successfully fabricated devices with a single engineered ^{31}P atom in a silicon matrix that can be controlled and read-out to a precision of 20 nm. The pilot experiments suggest that the present devices have the potential to be scaled up to engineered devices containing large-scale arrays of single atoms or colour centres. This presentation is a review of recent progress in these areas.

This work was supported by the Australian Research Council, the Australian Government and by the US National Security Agency (NSA), Advanced Research and Development Activity (ARDA) and the Army Research Office (ARO) under contracts W911NF-04-1-0290. The collaboration of colleagues from the ARC Centre of Excellence for Quantum Computer Technology is gratefully acknowledged.

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