Applied and Atomic Physics

Structural coatings, Surfaces studies and ionic implantation

The properties of the surface of different substrates are modified by means of two techniques: the first one is ion implantation with energies ranging between 100 to 400 keV and the second one is coating of a surface with a hard amorphous carbon film or a related material. The aim of the ion implantation techniques is to modify the properties or the crystalline structure of the surface of different materials. The purpose of the second one is to grow hard films using different ion beams, to protect the surface from the wear caused by abrasion or chemical attack. The principal protective coatings so far produced and studied are: hard amorphous carbon films (a:C) of about 1 mm thickness, N containing a:C films and amorphous carbon rich SiC films. The main idea is to establish a correlation between physics-chemical and tribological properties of these films. It is particularly relevant to determine which composition and microscopic structure give the compound greater thermal stability, hardness and /or wear resistance.

The physical properties of these films and of the modified substrate are evaluated by various methods: Raman spectroscopy to study the amorphous character of the films, XPS and EELS for structural and compositional studies, heavy ion beam techniques (HIRBS and ERDA) to determine the concentration of different elements in the film and on the treated surface and positron annihilations spectroscopy (PAS) to estimate the size of clusters forming the amorphous matrix. Tribological properties are studied measuring indentation hardness, elastic modulus, wear resistance and scratch damage.

In the last years, a wide range of new carbon structures (from polymeric to a-C) has been prepared from fullerene C_{60} under high pressures and temperatures. It has been demonstrated that high-pressure-induced polymerization or amorphization of solid C_{60} gives as a result superhard carbon structures with very interesting electrical behaviors. In our laboratory, the high pressure and high temperature are replaced by a dynamic process of deposition of fullerenes with different energies, inducing bonds between carbon atoms of neighboring C_{60} molecules, forming carbon films with different short range organization depending on the ion beam energy.

Hydrogen-free carbon films have been produced accelerating C_{60} ions on silicon substrates. C_{60}^{+} ions were obtained from fullerene powder at high temperature using a filament-discharge ion source. C_{60} ions have been accelerated to different energies (from 100 to 2000 eV) on the substrates.

The obtained films have been characterized by EELS, Raman spectroscopy, PAS, XPS, electrical resistivity and indentation hardness measurements.

During the last years, several developments have been performed using a heavy ion beam in the analysis of material (ERDA and HIRBS techniques), in particular, in the determination of the concentration profile of elements in the zone near of the surface of the material (around one micron).

At present our main objective is to reduce the difficulties connected with the ERDA technique, for example the gas handling system of our detector, the data analysis and the complicated experimental setup in general. To fulfill this we planned different tasks such as: improving the gaseous detector, developing a new data acquisition systems based on a standard personal computer (PC) and using a particular software for data analysis, and finally the installing a dedicated scattering chamber. In summary, the principal purpose is to develop a reliable experimental setup, which could be used by different groups without major difficulties to get high quality analytical results as fast as possible.

"Comparison of the Ablations performed by Different Excimer Laser Devices on Acrylic Plates"

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Refractive surgery is a technique in continuous evolution which no ophthalmologist should overlook. It is well known that there are many different types of laser devices available for photoablative surgery (PRK-LASIK) as a treatment for refractive errors. However, the results obtained with the different Excimer laser delivery systems when treating equal refraction amounts are inconsistent. These final results depend largely on the inherent constitutional features of each laser device. The aim of this paper is to analyze the homogeneity achieved by four different Excimer laser technologies.

"Amorphous Si_xC_{1-x} Films: An Example of Materials presenting Low Indentation Hardness and High Wear Resistance"

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Hardness is usually tested by indentation methods and is a measure of the pressure necessary to permanently affect a surface. However, our studies indicate that the wear and the indentation behavior could be not necessarily correlated in amorphous materials. Taking into account that in most industrial applications of thin films as protective coatings, wear resistance and adherence are usually the most important characteristics, is hardness, measured by indentation methods, the most relevant test to characterize their mechanical properties? Amorphous Si_xC_{1-x} films, with x ranging from 0 to 0.4, were grown by high-energy ion beam deposition starting from a methane-silane gas mixture. XPS analysis of the samples shows that it is possible to incorporate silicon to the amorphous carbon matrix giving a Si/C similar to the silane-methane ratio in the gas mixture. Raman spectra indicate that graphitization occurs from about 600 ºC up to 900 ºC as x increases from 0 to 0.4. In the present work, we study mechanical properties of these materials: indentation hardness, elastic modulus, wear resistance and scratch damage. Scratch tests show an excellent adherence of the films to the substrate with a mixed interface region. The hardness and elastic modulus of these films, measured by indentation methods, indicates values lower than that of silicon. The wear resistance has been measured by simultaneously polishing the films and silicon wafers with diamond powder (3 -micro-m). All these films have shown to be much more wearing resistant than the silicon wafers under polishing tests. This behavior has been observed even for films annealed up to 500 ºC. This apparent controversy between low indentation hardness and an extremely high wear resistance is discussed in the present work.

"New Compact Design for an Ion Source"

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The use of ion sources to generate beams of various species having different energies has been considered for a wide range of applications: production of new materials, particle accelerators, proton-therapy machines, ion-implantation systems, lithography, etc.. In particular, we produce thin films of amorphous carbon with some properties of diamond by deposition of hydrocarbon ions. Materials coated with these diamond-like films have demonstrated properties of biocompatibility and osseointegration. Recently, multicusp ion sources have been developed in many laboratories around the world. In their design, a set of columns of permanent magnets are arranged with alternating polarity to generate longitudinal line-cusp magnetic fields that can efficiently confine the primary ionizing electrons and the plasma. Both filament-discharge and radiofrequency (rf) induction discharge are used in the multicusp ion sources. We have redesigned an existing filament-discharge ion source by adding a set of permanent magnets at the external wall of the discharge chamber. We have tested different geometrical configurations of the magnets including the multicusp ion source configuration. In our final design, the external surface of the ion chamber is surrounded by four bars (1.2 cm x 3 cm x 5 cm) of magnets which are arranged 90° apart each other, with the same polarity pointing to the axis of the chamber. The permanent magnets are made of a metallic neodymium

alloy and have a field intensity of 0.34 T at contact. The plasma is contained in a thin-walled (3 mm-thick) stainless steel cylinder 3 cm diameter by 3 cm long. This new compact ion source can deliver a current of 2 mA with a minimum power in the filament-discharge stage. With a 1.5-mm diameter extraction aperture, a positive hydrogen beam current density of 100 mA/cm^2 can be obtained at a filament-discharge power of 100 W. Details of the design of this ion source and parameters of its operation will be presented and discussed. Tests of further improvements in the performance of the ion source are underway.

Positron Study of Defects in a-Si_xC_{1-x} Films Produced by Ion Beam Deposition Method"

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Amorphous a-Si_xC_{1-x} films with x ranging from 0 to 0.4 have been produced using a high energy ion beam deposition method. The resulting films have been characterized by Raman and Positron Annihilation spectroscopies. Hardness and wear resistance have also been measured. It has been shown that the open volume defects and their distribution through the films have an important role in determining the mechanical behavior of the as-deposited and thermal treated films.