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FIXLAB

Ion Beam Analytical techniques: Tandem 3 MV and Cyclotron

Description

When a sample is exposed to an ion beam, different atomic and nuclear processes are induced. As a result of these processes, several products are generated, and each product provides information on the properties of the material (composition, structure, etc.)
IBA (Ion Beam Analysis) is a generic term that encompasses a set of specific techniques, of which the main ones are:

- Rutherford Back-Spectrometry (RBS). The RBS analysis technique is multielemental and non-destructive. By means of RBS it is possible to know the elemental composition (stoichiometry) without standard and obtain the elemental profiles of concentration in depth. Surface impurities and the distribution of impurities in depth can also be known. Thin film thicknesses and interfaces can be measured. Through the use of Channeling-RBS, the location of impurities in the network of a monocrystal can be determined, as well as the distribution of defects in depth in the same.

-Analysis by Elastic Recoil Detection (ERDA). This technique is based on the physical foundations of elastic dispersion. In it heavy ion beams are used to collect the light recoil nuclei that leave the sample. ERDA is an efficient technique for obtaining depth profiles with high resolution.

-Analysis by Nuclear Reactions (NRA). Particle Induced ɣ- Rays Emission (PIGE). With the analysis by means of nuclear reactions (NRA) the profiles in depth of light elements in a non-destructive form are obtained, and elements such as H, D, Li, B, C, O and F can be analyzed. It is a technique complementary to the RBS, but the analysis by nuclear reactions is isotopically sensitive. Gamma radiation may appear among the products of a nuclear reaction, and it is then possible to perform PIGE. PIGE is normally used to measure Na, Mg, Al, Si and P.

- Particle Induced X-Rays Emission (PIXE). The PIXE technique is non-destructive and is used to obtain multi-element information of both major elements and trace elements. It is combined with RBS to obtain a more precise characterization of elements with an intermediate Z to heavy elements, and combines with NRA and PIGE to study elements of Z <12.

Fields of application	Materials
Cultural heritage Multielemental non-destructive characterization of any kind of objects.	Metal alloys (gold, silver, bronze, brass, etc ..), ceramics, glass, paintings , inks, stony material, ivory, bones, ...

Equipment

The first accelerator at CNA was a Pelletron 3 MV Tandem, model 9SDH-2, made by National Electrostatics Corporation (NEC). It is primarily focused on material characterization and modification by means of IBA techniques and ion implantation, as well as to the study and development of nuclear instrumentation, especially radiation detectors.

Ions are produced by three ion sources. The first one is based on radiofrequency techniques (Alphatross) and generates negative ions from gases (H, He, N, ...). There is also a caesium sputtering source (SNICS) which produces negative ions from solid samples. The most recent one is a Duoplasmatron source, which is very reliable and provides a high-brightness beam. The sources are connected by ports to an injection magnet that selects the desired ion mass.

Photons and particles are detected using standard detectors: SiLi and LEGe from Canberra, an Ortec HPGe, a NaI(Tl) detector and ion-implanted silicon detectors.

The Cyclotron was the second particle accelerator installed at CNA (year 2004). In this accelerator, ions are accelerated through the combined application of an electric and a magnetic field. It was manufactured by IBA (Belgium) and it accelerates protons and deuterons to 18 and 9 MeV, respectively. The extracted maximum beam intensities in the internal target ports are 80 μA ± 10% for protons and 35 μA ± 10% for deuterons.

The Cyclone 18/9 allows the simultaneous bombardment with the same particle of one or two targets that are located in opposite positions (Dual Beam Mode). Seven out of the eight targets are devoted to the production of positron emitters. Thus, CNA offers the possibility to produce the most frequent radioisotopes employed in the imaging modality Positron Emission Tomography (PET).

The research which requires the use of protons and deuterons in other fields like heritage science, with energies above 6 MeV, must be carried out in the Cyclotron beam transport line. Until 2010, it had worked in vacuum coupling the portable irradiation and implantation line. This line can be fixed to both, the 3 MV Tandem Accelerator and the Cyclotron. At 2010, it had been a number of changes in the line leading to expand the versatility of this accelerator. Regarding the energy of the particles, the compact Cyclotron is limited to supply 18 MeV protons and deuterons of 9 MeV. In 2010, a “true” external beam line has been installed, as the particle beam goes to the air before impacting on the target.

Potential Results

Highly sensitive non-destructive multi-element analysis (ppm) with the possibility of good depth resolution using IBA techniques for any type of material and size of objects

References

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Sample or service requisites

Generally, elaborate methods of sample preparation are not necessary. It is frequent that the sample can be analyzed directly, without any type of preparation, given the non-destructive nature of the techniques. The use of the external beam line also allows to analyze objects of any size and shape, making unnecessary in most cases the need for sampling.

Provider

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