Combined PIXE/PIGE with the high-energy beams of theARRONAX cyclotron

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Combined PIXE/PIGE with the high-energy beams of the ARRONAX cyclotron

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Ion Beam Analysis with the ARRONAX cyclotron beams

ARRONAX (Nantes, France) is a multi-particle cyclotron (Cyclone®70): protons can be accelerated from 30 MeV up to 70 MeV, deuterons from 15 MeV up to 35 MeV and alpha particles at fixed 68 MeV.

For ion beam analysis, protons are selected for their higher range in the matter, alpha for their higher PIXE sensitivity (K X-ray production cross section) and low energy deuterons essentially for PIGE.

Main features:
- multi-elemental analysis (ppm) thanks to K X-ray detection
- fast, non-destructive, in normal air
- thick/multilayer samples
- density and stoichiometry measurement

Multi elemental analysis


X-rays are detected in normal air with a LEGe detector (Canberra GL005P, Be window) at an angle of detection 0 = 135° (see Fig. 1). The distance between sample and detector varies from 5 to 25 cm (dependent on experimental requirements). The number of incident particles is measured either with a 2 µm monitor copper foil or the argon (in air) peak (previously calibrated). The beam diameter is few mm and the intensity is <1nA.

The limit of detection (LoD) reaches the ppm for medium and heavy elements in thick matrix. Table 1 presents the limit of detection for different elements.

<table>
<thead>
<tr>
<th>Table 1 – Limit of detection for different elements</th>
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<tr>
<td>Element</td>
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<td>Ag</td>
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For the analysis of low atomic elements, two additional detectors have been used: light element detection: complementary PIGE and SDD X-ray detection to the samples and a large LaBr3 detector for thick and multilayer samples.

For the analysis of medium and heavy elements, the high energy PIXE set (100 MeV proton beam) was used. As part of improving the detection of light elements, two additional detectors have been used: Light element detection: complementary PIGE and SDD X-ray detection.

As part of the development of new methods for the determination of water content in soil samples using gamma rays, light elements can be analyzed thanks to the gamma rays (PIGE).

Graphs and figures:
- Fig. 1 – high energy PIXE set-up with the beam extraction window and collimators (center), the shielded X-ray LEGe detector (left), the X-ray silicon drift detector (top) and the automated sample holder (right).
- Fig. 2 – limit of detection of lake sediment IAEA RM SL-1 matrix
- Table 2 – characteristics of the soil samples and the reference one (IAEA RM SL-1).
- Fig. 3 – electrodeposited Ni/Ga alloy on gold substrate
- Fig. 4 – X-ray spectrum from irradiation of the Ni/Ga (gold) substrate target with a 70 MeV proton beam (LEGe detector at 25 cm).
- Fig. 5 – gamma-ray spectra obtained for 2 samples of different sands.

Multi elemental analysis

[Graph and table data]

Bulk analysis (density and stoichiometry)

Determination of the thickness, the density and the mass fraction of a Ni/Ga alloy deposited on a gold substrate (to be used as target at ARRONAX for production of a 110Ge/68Ga generator for medical imaging).

The thickness of the alloy is then determined thanks to the attenuation of the K X-ray coming from the gold carrier.

Light element detection: complementary PIGE and SDD X-ray detector

As part of improving the detection of light elements, two additional detectors have been used:
- A HPGe detector (from Canberra, 50 mm diameter and 57 mm depth) gamma-rays and a Silicon Drift Detector (SDD from Ketek) for low energy X-rays.
- Two different types of sand have been irradiated with a 16 MeV deuteron beam;
- The HPGe gamma detector was located at 100 cm from the target and the SDD for low energy X-rays at 2.3 cm (see Fig. 1).

- the limit of detection with X-rays is improved for light elements (down to Al, Z=13, at least) with the additional detector (compact SDD);
- lighter elements (such as Oxygen in this case) can be analyzed thanks to gamma rays (PIGE);
- a method to determine the water content of soil samples using gamma rays is being developed (from this study with sands).

[Graph and table data]

summary and outlook

A high energy PIXE platform is now available at ARRONAX. It is well suited for in-air multi-elemental analysis (at the ppm level for medium and heavy elements) and bulk analysis (stoichiometry, density, etc.) of thick and multilayer samples.

For the analysis of low atomic number elements, an additional Silicon Detector can be used closer to the samples and a large LaBr3 detector will be soon installed to develop the complementary PIGE method.

[Contact and website information]