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CdTe detector based PIXE mapping of geological samples

P.C. Chaves [a,b,*], A. Taborda [a,b], D.P.S. de Oliveira [c], M.A. Reis [a,b]

[a] Centro de Física Atómica da Universidade de Lisboa, Av. Prof. Gama Pinto 2, 1649-003 Lisboa, Portugal
[b] IST/ITN, Instituto Superior Técnico, Universidade Técnica de Lisboa, Campus Tecnológico e Nuclear, EN10, 2686-953 Sacavém, Portugal
[c] Laboratório Nacional de Energia e Geologia (LNEG), Apartado 7586, 2611-901 Alfragide, Portugal

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ABSTRACT

A sample collected from a borehole drilled approximately 10 km ESE of Bragança, Trás-os-Montes, was analysed by standard and high energy PIXE at both CTN (previous ITN) PIXE setups. The sample is a fine-grained metapyroxenite grading to coarse-grained in the base with disseminated sulphides and fine veinlets of pyrrhotite and pyrite. Matrix composition was obtained at the standard PIXE setup using a 1.25 MeV H^+ beam at three different spots. Medium and high Z elemental concentrations were then determined using the DT2fit and DT2simul codes (Reis et al., 2008, 2013 [1,2]), on the spectra obtained in the High Resolution and High Energy (HRHE)-PIXE setup (Chaves et al., 2013 [3]) by irradiation of the sample with a 3.8 MeV proton beam provided by the CTN 3 MV Tandetron accelerator. In this paper we present results, discuss detection limits of the method and the added value of the use of the CdTe detector in this context.

1. Introduction

The determination of Rare Earth Elements (REE) in geological samples is a very important subject but hard to tackle. Standard PIXE can be used for the analysis of REE, but the REE L X-rays energies from about 4–9 keV strongly overlap with K X-rays energies of the light elements ($20 < Z < 30$), and the quantification of REE by PIXE becomes very difficult and inaccurate as a results of the needed complex spectra deconvolution. In fact, in the context of REE L X-rays, Nekab [4] using a standard PIXE setup compares results obtained with PIXE, XRF and NAA for geological samples and concludes that with the PIXE technique the limits are 30 ppm for REE, higher than with other techniques as NAA. The use K X-rays of REE elements could be a solution but at that energies Si(Li) detectors can no longer be used. To overcome this problem the use of large Ge detectors to detect the K X-rays of REE was attempted, but due to their large dimensions, a large Compton background is present, which degrades the detection limits in the high X-ray energy region. Small Ge detectors [5,6], represent an improvement relative to this problem, but their overall size is still significative leading to an overall reduced solid angle. CdTe crystals having an average atomic number of 50 allow the construction of small detectors. This makes possible overcoming the Compton problem at the same time as it solves solid angle problems since they can be placed very close to the sample. CdTe detectors are thus a good possibility for High Energy PIXE.

In this study, a metapyroxenite sample collected in the North of Portugal at Bragança – Trás-os-Montes, was analysed by standard and High Energy PIXE at CTN (previous ITN) PIXE set-ups. The sample is a fine-grained metapyroxenite grading to coarse-grained in the base with disseminated sulphides and fine veinlets of pyrrhotite and pyrite. Mapping of medium and high Z elements including REE were carried out and are discussed.

2. Materials and methods

In the present work, experiments were carried out at the two PIXE setups at the CTN: (i) the 2.5 MV Van de Graaff standard PIXE setup [7] and (ii) the 3.0 MV Tandetron high resolution high energy (HRHE)-PIXE setup [8,9,3].

The CTN standard PIXE setup makes use of a Si(Li) 150 eV resolution detector kept at an angle of 110° relative to beam direction [7]. Three low energy spectra were collected during irradiation with 1.25 MeV H^+ ion beams at an incidence angle of 30°. A Ta collimator with a thickness of 1 mm and a diameter of 4.7 mm was placed in front of Si(Li) detector. The irradiation spots were chosen in order to have the most different visual spots, being the second one corresponding to the bright area of the sample. The selected spots can be seen in Fig. 1 and are labelled as S1, S2 and S3.

The experiment carried out at the HRHE-PIXE setup made use of the Amptek Peltier Cooled $3 \times 3 \times 1$ mm^3 CdTe detector placed at 35° into the beam direction and has a 250 μm Beryllium window. More details about the HRHE-PIXE setup can be found in [3]. At the

* Corresponding author at: Centro de Física Atómica da Universidade de Lisboa, Av. Prof. Gama Pinto 2, 1649-003 Lisboa, Portugal. Tel.: +351 219946065; fax: +351 219946285.
E-mail address: cchaves@ctn.ist.utl.pt (P.C. Chaves).

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