CdTe detector use in PIXE characterization of Sn dopped CdO thin films

P.C. Chaves, O.R. Oliveira, V. Corregidor, N. P. Barradas(1,2) and M.A. Reis

(1) ITN, EN10 Sacavém, Apartado 21, 2686-953 SACAVÉM, PORTUGAL
(2) Centro de Física Nuclear da Universidade de Lisboa, Av. Prof. Gama Pinto 2, 1649-003, Lisboa, PORTUGAL

O. Vigil Galán
Departamento de Física de Materiales, Universidad Autónoma de Madrid, 28049 Madrid, SPAIN

A. Arias Carbajal
Facultad de Química-IMRE, Universidad de La Habana, 10400, La Habana, CUBA

ABSTRACT

Low peak to tail ratio detectors are usually assumed to be unsuitable for PIXE due to the associated degradation of the detection limits. Still, when K-shell x-rays from intermediate and high atomic number elements are involved, a Peltier cooled CdTe detector may be used and high graded results achieved. In the present work, a case study is discussed pertaining the determination of Sn on a CdO thin film deposited on a soda-lime glass substrate. This is a complex problem for IBA techniques due to the overlapping conditions found in both PIXE and RBS. In the present work, partial thickness of the order of 0.5µg/cm² of Sn could be determined on a 50µg/cm² CdO film by using the Sn Kβ x-ray lines for quantification. This approach makes use of the good efficiency of the CdTe detector at 28keV energy, usually near the end of the usable energy range for a Si(Li) detector. The combination of PIXE and RBS data for such problem will also be emphasised, namely by showing that some uncertainties in spectra interpretation can be overcome in this way.

Keywords: CdTe detector, PIXE analysis, Thin films

1. INTRODUCTION

In this work a case study of the use of a CdTe detector in a PIXE system is presented. These detectors have a good efficiency beyond the range of energies normally covered by Si(Li) detectors, commonly used in PIXE analysis. The detection of the K x-rays from a sample of W, presented in figure 1, is a good example of this. Apart from these special cases, CdTe detectors are also useful for some common tasks in PIXE. IBA analysis of thin films of elements having medium or close atomic numbers is such a case. It will be shown that the combination of RBS and CdTe based PIXE can be used to overcome the characterization problems posed for these samples.

![FIGURE 1](image-url): Typical PIXE spectra of W thick sample collected by the CdTe detector at the 70º window. The good efficiency and resolution at 60 keV is clear from the right hand detail of the W K x-rays.
The present work describes the use of a CdTe detector for the PIXE analysis of two CdO thin films doped with Sn (CdO:Sn). In this case study the high tail characteristics of the CdTe detector were overcome using a grazing detection geometry [1] combined to the good detection efficiency of the CdTe detector for the Cd and Sn K x-ray energies.

2. EXPERIMENTAL

The detector used for PIXE was an Amptek Peltier Cooled 3x3x1 mm CdTe detector installed at ITN 2.5 MV Van de Graaff PIXE setup. This detector has a 250 µm Beryllium window and a small size: 9.5x4.4x2.9 cm. It can thus be easily coupled to the PIXE chamber in addition to a standard Si(Li) LN cooled detector. This CdTe useful energy range starts at K-K\(_\alpha\) (3.312 keV) and goes up to more than 110 keV, the energy of one of the γ-ray from the \(^{19}\text{F}(p,\alpha\gamma)^{16}\text{O}\) reaction. Presently two settings can be used. In one the CdTe is placed at 90º to the beam direction, while in the other setting the CdTe is placed at 70º to the beam direction. In either case the CdTe detector is coupled to the PIXE chamber by a Perspex sleeve, which contains the chamber window. In the 90º setting the chamber window consists of a 0.5 mm Perspex wall. In the 70º setting a 400µm Al plus 2 mm Perspex funny filter structure is place on top of 0.5 mm Perspex wall. The funny filter hole being 0.7 mm in diameter (1.4% of the detector solid angle).

Figure 1 presents a spectrum of W obtained by irradiation of a thick W foil with a 2.4 MeV H\(^+\) beam, using the CdTe detector on the 70º setting. Although the resolution at the L x-rays is just reasonable (roughly 4 to 5%) the CdTe detector performance at 60 keV is very good showing a 1.1% resolution that allows a very nice K\(_{\alpha 1}\) and K\(_{\alpha 2}\) peaks separation.

In the case of the CdO:Sn samples a 2.1 MeV H\(^+\) beam was used for irradiation of the samples positioned at an angle of 15º to beam direction. The 90º setting of the CdTe detector was used, which renders a detection angle of 75º. Spectra were deconvoluted using the AXIL code [2] and quantitative data were then obtained using the DATTPIXE package [3,4]. RBS analysis was done with a 2 MeV He\(^+\) beam and RBS data analysis was done with NDF [5].

3. RESULTS AND DISCUSSION

The two CdO:Sn films were deposited by spray pyrolysis on top of a soda-lime glass substrate [6]. Details of the RBS and PIXE spectra of these thin films are shown in figure 2. A complex overlap of the signals coming from the Sn and Cd elements is identifiable in the RBS spectra, due to the similar atomic masses of the components, figure 2(a). In the case of Sn1.5 sample a displacement for higher energies is observed. Combining RBS and PIXE data, figure 2(b), it is possible to identify this difference in the RBS spectra as being due to a high Sn concentration in the film.

![FIGURE 2: a); RBS spectra of CdO:Sn thin films on a glass substrate. b) PIXE Spectra of CdO:Sn thin films, with a CdTe detector, normalized to the Cd-K\(_{\alpha 1,2}\) of the Sn1.5 sample.](image-url)
Quantitatively the Cd and Sn results for superficial mass were determined by PIXE considering the samples as thin samples. Sn concentrations were based on the K\textsubscript{\beta} peaks, which are located on a flat background of the spectra. The composition and the errors obtained are presented in the Table 1. RBS data obtained for Cd by applying NDF and the Sn/Cd ratios from PIXE are also shown. It can be seen that the two techniques are not in agreement. A possible interpretation for this being the diffusion of the elements deep into the sample in such a way that the RBS technique detection limits are not reached in the substrate. PIXE on the other side, both because it makes use of a H\textsuperscript{+} beam (having deeper penetration) as well as x-ray presenting low autoabsorption coefficients, carries out a deeper inspection into the sample. PIXE, therefore does not loose an eventual substrate diffused component, even in a grazing detection geometry.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cd (µg/cm\textsuperscript{2})</th>
<th>Sn (10\textsuperscript{15} at/cm\textsuperscript{2})</th>
<th>Sn/Cd (at %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn1.0</td>
<td>RBS data (b) 347</td>
<td>120</td>
<td>642 5</td>
</tr>
<tr>
<td></td>
<td>(a) 347</td>
<td>(b) 120</td>
<td>(c) 642 5</td>
</tr>
<tr>
<td></td>
<td>(a) 347</td>
<td>(b) 120</td>
<td>(c) 642 5</td>
</tr>
<tr>
<td>Sn1.5</td>
<td>288</td>
<td>92</td>
<td>491 5</td>
</tr>
<tr>
<td></td>
<td>288</td>
<td>92</td>
<td>491 5</td>
</tr>
<tr>
<td></td>
<td>288</td>
<td>92</td>
<td>491 5</td>
</tr>
</tbody>
</table>

4 CONCLUSIONS

The results of this study show that it is possible to use a CdTe detector for PIXE even in cases as complex as that of the analysis of thin films of elements having medium or close atomic numbers. The use of grazing detection geometry helps but, above all, the good efficiency for high energies opens solutions hardly available to Si(Li) detectors, or totally excluded as is the case of detecting the K x-rays from W. CdTe detectors have therefore their own place in the future of PIXE.

ACKNOWLEDGMENTS

This work has been supported by the EC project HPRN-CT-2001-00199.

REFERENCES