MÖSSBAUER BACKSCATTERING MEASUREMENTS ON EU-151

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The possibility to make surface measurements in the nano or micro range by Mössbauer spectroscopy using ¹⁵¹Eu Mössbauer isotope is demonstrated. Measurements were made with a new flow detector in a backscattering geometry. With this detector it is possible to detect conversion electrons or low energy X-rays. An Eu₂O₃ sample has been used. These measurements have been performed for the first time in Romania.

Key words: Mössbauer spectroscopy, Surface measurements, ¹⁵¹Eu, Eu₂O₃.

1. INTRODUCTION

Mössbauer spectroscopy [1–3] is based on the resonant recoil free absorption and emission of low energy γ-rays; the effect is significant when the nuclei are imbedded in a rigid matrix. The line width of the emitting photon is very narrow resulting from the relatively long lifetime of the excited nuclear state – typically of 10⁻⁸ s, corresponding to a natural line width of the order of 10⁻⁸ eV. Thus it is possible to probe the variations in nuclear energy levels resulting from any discrete changes in the chemical state and/or environment of the Mössbauer nucleus. Following resonant absorption of a gamma ray, the nucleus may de-excite by emission of a gamma ray or by the process of internal conversion where an inner shell electron is emitted. A characteristic X-ray is emitted as a result of the repopulating of the inner energy levels, accompanying conversion electron emission. The surface studies can be performed at various depths by detection of the three backscattered particles (γ-rays, X-rays, conversion electrons). The smallest depths can be investigated by electron emission. The conversion signal is large for the ⁵⁷Fe, ¹¹⁹Sn and ¹⁵¹Eu isotopes. The measurements for the ⁵⁷Fe have been already performed [4, 5].

It is important to extend surface studies for ¹⁵¹Eu isotope. Coatings and thin films containing Eu can be studied, thus, in scattering geometry, through the
detection of emitted conversion backscattered radiation. The secondary radiations
emitted by the de-excitation of the 21.54 keV nuclear excited state of $^{151}$Eu are
presented in Table 1 [6, 7].

There are not conversion electrons emitted by the de-excitation of $^{151}$Eu
isotope, in contradistinction with $^{57}$Fe and $^{119}$Sn isotopes [4, 5].

Table 1

<table>
<thead>
<tr>
<th>Secondary Radiation</th>
<th>Energy [keV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$-ray radiation</td>
<td></td>
</tr>
<tr>
<td>$\gamma_M$ ray</td>
<td>21.54</td>
</tr>
<tr>
<td>X-ray transition</td>
<td></td>
</tr>
<tr>
<td>$L_\alpha$ line</td>
<td>5.843</td>
</tr>
<tr>
<td>$L_\beta$ line</td>
<td>6.571</td>
</tr>
<tr>
<td>$L_\gamma$ line</td>
<td>7.644</td>
</tr>
</tbody>
</table>

2. EXPERIMENTAL

The measurements were made, at room temperature, with a new
constructed, versatile flow-gas proportional counter for surface Mössbauer
spectroscopy [8], suitable for studies with all mentioned isotopes. Its design is
better than those previously reported [4, 5]. It was designed in a cylindrical
geometry. It has the following main advantages: (i) the height of the detection
volume can be changed in large limits from 0 to 38 mm, (ii) the detection
volume can be choose symmetrical or not in respect with anode plan, (iii) the
anode replacement is easily and (iv) different anode configuration can be used.
By changing the volume detection and flow gas (94% He + 6% CH$_4$ or 99% He
+ 1% C$_4$H$_{10}$ for electrons; 92% Ar + 8% CH$_4$ for X-ray) it is possible to make
Mössbauer measurements by electron or X-ray detection. The sample holder
allows an easy manipulation of the sample, outside the detector and can always
be repositioned in a reproducible manner with respect to the detector body. The
holder also allows performing simultaneously surface and transmission
measurements. The Eu$_2$O$_3$ [9] powder has been used as sample. For
backscattering measurements it has been deposited on support by a solvent. The
samples for transmission had two superficial weights: 10 (sample 1) and
20 mg/cm$^2$ (sample 2). We used an 80 mCi $^{151}$Sm diffused in samarium oxide,
source supplied by Amersham QSA. Measurements were carried on Elscint
AME-50 Mössbauer spectrometer by inserting the mentioned flow gas
proportional counter into spectrometer. In order to absorb unfavourable
Eu L X-rays (5.84 $\div$ 7.64 keV) from the source, a thin aluminium filter is placed.
in front of the detector. This filter can absorb more than 80% of the X-rays. The surface measurements have been conducted at a high degree of accuracy, ensuring the same geometry of the detection space and the same gas flow rate for measurements.

The parameters of the Mössbauer spectra were calculated using a computer fitting program, which assumes a Lorentzian line shape. The isomer shifts were referred to $\alpha$-Fe.

3. RESULTS

The pulse height spectrum of photons backscattered from the Eu$_2$O$_3$ sample, placed inside the detector, is reproduced in Fig. 1.

The amplitude spectrum of the backscattered photons obtained without filter, Fig. 1, displays a visible structure and has a good resolution for low energy X-ray and low effectiveness for Mössbauer radiation. This fact proves the performance of the detector.

Fig. 2 shows the Mössbauer spectra of the Eu$_2$O$_3$ sample obtained by detection of conversion X-rays. The data obtained by backscattering measurements carried on Eu$_2$O$_3$ samples using the detection of conversion X-rays are presented in Table 2.

Also we obtained the transmission spectra of the sample by the detection of Mössbauer gamma-ray and conversion X-ray. The results obtained are presented in Table 3.

![Pulse height spectra of photons scattered from a Eu$_2$O$_3$ sample.](image-url)
Fig. 2 – Conversion X-rays Mössbauer spectrum of Eu$_2$O$_3$ sample.

**Table 2**

Data obtained by backscattering measurements carried on Eu$_2$O$_3$ samples using the detection of conversion X-rays

<table>
<thead>
<tr>
<th>Conversion X-rays</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon$</td>
</tr>
<tr>
<td>Eu$_2$O$_3$</td>
</tr>
<tr>
<td>Sample</td>
</tr>
</tbody>
</table>

**Table 3**

Data obtained by transmission measurements carried on Eu$_2$O$_3$ samples using the detection of gamma-rays and conversion X-rays

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\varepsilon$</th>
<th>$w$</th>
<th>$N$</th>
<th>$\varepsilon$</th>
<th>$w$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.74</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.5%$</td>
<td>16.93</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.5%$</td>
</tr>
<tr>
<td>2</td>
<td>16.93</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.5%$</td>
<td>20.16</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.5%$</td>
</tr>
</tbody>
</table>

The parameters of Mössbauer spectra calculated using a computer-fitting program, which assumes a Lorentzian line shape are presented in Tables 2 and 3 where:

- $\varepsilon$ represents resonance effect measured in %; error $\pm 0.15\%$;
- $w$ represents linewidth measured in mm/s; error $\pm 0.02$ mm/s;
- $N$ represents average count rate measured in number/s; error $\pm 0.5\%$. 
In the backscattering geometry the line width are smaller. The smaller line width is expected in the backscattering geometry due to lack of saturation broadening. The smaller resonance effect, obtained in the detection of the conversion X-rays is compensate by significant smaller line width. In the backscattering measurements the counting rates are lower than in transmission measurements. It is clear that transmission X-rays represent a true alternative to transmission gamma rays.

4. CONCLUSIONS

The possibility to make surface measurements in the nano or micro range by Mössbauer spectroscopy using $^{151}$Eu Mössbauer isotope it is proved. Measurements were made with a new flow gas detector in a backscattering geometry using Eu$_2$O$_3$ powder sample. Data for surface information have been obtained by detection of X-rays. These measurements were performed for the first time in Romania. Transmission X-rays represent a true alternative to transmission gamma rays measurements accomplished for $^{151}$Eu Mössbauer isotope.

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