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TEMPERATURE VARIATION OF HYPERFINE MAGNETIC FIELD IN $\text{Co}_2\text{MnZ}$ AND $\text{Co}_2\text{TiZ}$ ($Z = \text{Si, Ge, Sn}$)

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Abstract. — The temperature variation of the hyperfine magnetic field ($\text{hf}$) at $\text{Cd}-111$ in $\text{Co}_2\text{MnZ}$ and at $\text{Sn}-119$ in $\text{Co}_2\text{TiZ}$ ($Z = \text{Si, Ge, Sn}$) was measured respectively by perturbed angular correlation and Mössbauer techniques. In $\text{Co}_2\text{MnZ}$ the $\text{hf}$ follows the temperature variation of magnetization, but in $\text{Co}_2\text{TiZ}$ it deviates significantly.

Introduction

There have been many measurements of hyperfine magnetic fields ($\text{hf}$) at s-p element probes in $L_21$ Heusler alloys, which have the composition $X_2YZ$. When $Y$ is Mn and it is the only atom carrying a moment, the temperature variation of the $\text{hf}$ follows that of the magnetization reasonably well [1-2]. When more than one atom has a moment, the temperature variation of the $\text{hf}$ is likely to deviate from that of the magnetization. Delyagin et al. [3] measured $\text{hf}$ at Sn-119 impurity in $\text{Co}_2\text{MnZ}$ and found small deviation for $Z = \text{Si}$ and spectacular deviation for $Z = \text{Ge}$, with $H(0.75 T_M) \gg H(0)$ reminiscent of Os-192 $\text{hf}$ in Fe [4, 5]. $\text{Co}_2\text{MnSi}$ and $\text{Co}_2\text{MnGe}$ have respectively $T_M = 985$ K and 905 K, and the $\text{hf}$ on Sn-119 is small so the Zeeman pattern is not well resolved. Investigation of temperature variation of $\text{hf}$ at s-p element probe can be better done by time differential perturbed angular correlation (TDPAC) with Cd-111, which is being reported here. Among Heusler alloys $\text{Co}_2YZ$ where the moment is only on Co and is not well localized, Görlich et al. [6] found the temperature variation of the $\text{hf}$ at Sn-119 in $\text{Co}_2\text{TiSn}$ follows that of the magnetization. The studies are extended here to include $\text{Co}_2\text{TiSi}$ and $\text{Co}_2\text{TiGe}$.

Experimental techniques

Heusler alloys $\text{Co}_2\text{MnZ}$ ($Z = \text{Si, Ge, Sn}$) were prepared by powder metallurgy. $\text{Co}_2\text{TiSn}$ and $\text{Co}_2\text{TiZ}_{0.98}$ ($Z = \text{Si, Ge}$) were made by induction melting; for the latter two, 2 at % $^{119}\text{Sn}$-enriched Sn was subsequently added by powder metallurgy. X-ray diffraction showed the samples were single-phase. The $\text{hf}$ at Sn-119 was measured by the Mössbauer technique. For $\text{Co}_2\text{MnZ}$ carrier-free In-111 was diffused into the samples and the $\text{hf}$ at Cd-111 was measured with the TDPAC technique [1, 2]. Measurements at low temperatures were made with the sample immersed in cryogenic fluid; high temperatures were achieved with the sample in an electric resistance furnace.

Results and discussion

Figure 1 gives TDPAC spectra of In-111 in $\text{Co}_2\text{MnGe}$, and figure 2 gives Mössbauer spectra of Sn-119 in $\text{Co}_2\text{TiSi}$. The 295 K spectrum in figure 2 contains a line with no measurable splitting, attributed to small or no $\text{hf}$ at Sn in the Si site, also $\text{hf}$ of 63 kOe attributed to Sn at some other site. The unresolved Zeeman pattern in the $\text{Co}_2\text{TiZ}$ spectra, despite $\text{hf}$ of up to 80 kOe, indicates site disorder for Sn-119.

Fig. 1. — TDPAC spectra of In-111 in $\text{Co}_2\text{MnGe}$ and A) 822 K, B) 672 K and C) 77 K.

The Co-based Heusler alloys have nonlocalized moment contributed by Co. The resulting $\text{hf}$ is detected by Cd-111 and Sn-119 probes at the Z site; values at 77 K are given in table I. Temperature variation of $\text{hf}$
Table I. - Hmf in kOe. Sign undetermined unless shown.

<table>
<thead>
<tr>
<th>Host</th>
<th>$H$ (Cd - 111)</th>
<th>$T$ (K)</th>
<th>Host</th>
<th>$H$ (Sn - 119)</th>
<th>$T$ (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co$_2$MnSi</td>
<td>$-260 \pm 5$</td>
<td>293</td>
<td>Co$_2$TiSi</td>
<td>$80 \pm 3$</td>
<td>77</td>
</tr>
<tr>
<td>Co$_2$MnGe</td>
<td>$-256 \pm 5$</td>
<td>77</td>
<td>Co$_2$TiGe</td>
<td>$66 \pm 3$</td>
<td>77</td>
</tr>
<tr>
<td>Co$_2$MnSn</td>
<td>$-210 \pm 5$</td>
<td>77</td>
<td>Co$_2$TiSn</td>
<td>$78 \pm 3$</td>
<td>77</td>
</tr>
</tbody>
</table>

Fig. 2. – Sn-119 Mössbauer spectra of Co$_2$TiSi$_{0.98}$Sn$_{0.02}$ at A) 295 K and B) 77 K.

Fig. 3. – Temperature variation of Cd-111 hmf in Co$_2$MnZ. The line is magnetization of Co$_2$MnGe [7].

The temperature variation of the hmf at Cd-111 in Co$_2$MnZ, with $Z =$ Si, Ge and Sn, is found not to deviate dramatically from that of the magnetization. This is in contrast to the result of Delyagin et al. [3] for hmf at Sn in Co$_2$MnSi and Co$_2$MnGe. If their result is correct, it is difficult to see why the Cd probe, also an s-p element at the Sn site, would not show similar deviation.

Fig. 4. – Temperature variation of Sn-119 hmf in Co$_2$TiZ. The line is magnetization of Co$_2$TiSn [8].

The temperature variation of the hmf at Sn-119 in Co$_2$TiZ, with $Z =$ Si, Ge and Sn, is found to be similar for all three cases, and also to deviate from that of magnetization, unlike the previous result of Görlich et al. [6]. It is found that the hmf measured is dependent on sample preparation; this may explain the difference.

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