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A MÖSSBAUER DETERMINATION OF A POSITIVE $H_{\text{eff}}$ AT Sn$^{119}$ NUCLEI IN Cu$_2$MnSn HEUSLER ALLOY

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Abstract. — Using circularly polarized Mössbauer $\gamma$-rays, the sign of the nuclear hyperfine field at Sn$^{119}$ in the ordered ferromagnetic Heusler alloy Cu$_2$MnSn is shown to be positive. All previously measured fields at various nuclei in different Heusler alloys have (with the exception of that at Sn in Cu$_2$MnSn) been negative, and have all (including the positive value in Cu$_2$MnSn) been in fairly good agreement regarding magnitude and sign with the theoretical predictions obtained by assuming an oscillating conduction electron spin polarization around the Mn atoms.

The present work on Cu$_2$MnSn thus represents the first dramatic departure from the prediction obtained using this theory.

1. Introduction. — Heusler alloys have compositions near the formula Cu$_2$MnX ($X = \text{Al, In, Sn}$), and are ferromagnetic in the ordered $\beta$-phase (Heusler [1]). The magnetic moment per molecule is always about $4 \mu_B$ and is almost entirely carried by the Mn ions [2] [3]. The ferromagnetic coupling mechanism between the Mn moments is not entirely understood, but a model utilising the concept of resonant bound states for the 3d electrons of Mn atoms [4] accounts for many features of these alloys including most of the hyperfine fields at the constituent nuclei.

Previous measurements of hyperfine fields at constituent nuclei in various Heusler alloys, including the all-important sign determinations, have been tabulated by Williams [5] together with the theoretical estimates obtained using the theory of Caroli and Blandin [4] with which they are in remarkably good agreement. The present work on Cu$_2$MnSn thus represents the first dramatic departure from the prediction obtained using this theory.

2. Experimental Method. — The magnitude and sign of the hyperfine field at Sn$^{119}$ nuclei in Cu$_2$MnSn were measured using circularly polarized Mössbauer $\gamma$-rays in a similar way to that described in [5].

3. Results. — The Mössbauer absorption spectra measured $a$) with no applied magnetic field, and $b$) with source and absorber in a large longitudinal applied field, are shown in figure 1 and 2 respectively. As seen in figure 1 in addition to the expected 6 line magnetically split spectrum (in this case, the lines are not fully resolved) there is a central single line. This line is attributed to free Sn in a non-magnetic environment. The solid curve thus shows a computer fit representing the superposition of a single line and a 6-line magnetic spectrum whose relative line positions are fixed by the known Sn$^{119}$ nuclear g-factors for the ground and excited states.

In the presence of a longitudinal applied field, in addition to the 8-line polarization spectrum for the magnetic phase, there will be a 3-line polarization spectrum due to the non-magnetic Sn. Figure 2 shows the experimental polarization spectrum together with an 11-line ($8 + 3$) computer fit. The polarization spectrum depends critically on the direction of $H_{\text{eff}}$ relative to the applied field $H_{\text{app}}$, and figure 3 shows the predicted spectra constructed by assuming $a$) $H_{\text{eff}}$ positive, i.e. parallel to $H_{\text{app}}$, and $b$) $H_{\text{eff}}$ negative, i.e. opposite to $H_{\text{app}}$. It is
therefore, obvious that $H_{\text{eff}}$ is \textit{positive} and has the value +260 kOe at 4.2 °K. Previously measured fields have all been in fairly good agreement with the predictions based on the theory \cite{4} \cite{5} in which they are attributed to oscillations in the conduction electron spin polarization induced by Mn moments. Such a calculation of the field at Sn in Cu₂MnSn yields a value of approximately $-300$ kOe. Shinharra \cite{6} in a similar calculation based on the R. K. K. Y. interaction obtains a value of $-157$ kOe.

It is thus clear that such models are not accurate and the good agreement with experiment must in some cases be fortuitous. This is not unexpected as the calculations involve several uncertain parameters, in addition to assuming the asymptotic form of the spin density oscillations even at near neighbour distances.

References

\cite{1} HEUSLER (O.), \textit{Ann. Phys.}, 1934, \textbf{19}, 155.