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MÖSSBAUER STUDIES OF AMORPHOUS \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \)

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Abstract.-Magnetic ordering temperature \( T_C \) and the magnetic hyperfine interaction of amorphous \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \) \((0.375 \leq x \leq 1)\) have been determined by \( ^{57}\text{Fe} \) Mössbauer spectroscopy. The average exchange interaction of \( J_{\text{FeNi}} = 1.5 \text{ J}_{\text{FeFe}} \) and \( J_{\text{NiNi}} = 0 \) have been deduced. The hyperfine field distributions \( \langle P(H) \rangle \) are well-defined and show only a slight asymmetry about \( H_{\text{peak}} \), the peak value of \( P(H) \). \( H_{\text{peak}} \) and \( \langle P(H) \rangle \) decrease whereas the average isomer shift increase as Fe concentration is reduced. A noticeable amount of Fe atoms have a saturation field higher than 340 kOe, the saturation value for crystalline \( \alpha\text{-Fe} \).

1. Introduction.- Most of the amorphous magnetic solids studied to date fall into two categories: rare earth-transition metal systems and transition(TM)-metalloid systems /1/. In the case of the latter the TM concentration typically is about 80 \( \pm \) 5 at.\%.

It is tempting to compare the behavior of the TM-metalloid system with that of crystalline TM alloys and several have done so. In this work, amorphous samples of \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \) have been studied. It is shown that the properties of the (Fe-Ni)-metalloid samples are quite different from those of Fe-Ni alloys.

2. Experimental. - Amorphous samples of \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \) were prepared by the rotating drum method /2/. Samples with Fe concentration much less than 30 at.\% could not be made amorphous. The "as-prepared" samples were used in the \( ^{57}\text{Fe} \) Mössbauer spectroscopy measurements.

3. Results and discussion.- 3.1. Curie Temperature \( T_C \). - The magnetic ordering temperatures \( T_C \) of \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \) have been determined by the onset of the magnetic hyperfine interaction. These values are shown in figure 1 as a function of Fe concentration. The values for samples with \( x=0.75 \) and 0.875 have larger errors due to the proximity of crystallization to \( T_C \). These values are in good agreement with those of Becker et al. /3/ determined from magnetic measurements.

For comparison, the values of \( T_C \) for amorphous

\( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{P}_{14}\text{B}_{6} /4/ \) are also shown in figure 1.

![Figure 1: \( H_{\text{peak}} \), \( \langle P(H) \rangle \), \( \text{average isomer shift} \) and \( T_C \) for amorphous \( (\text{Fe}_x\text{Ni}_{1-x})_{80}\text{B}_{20} \) and \( \alpha\text{-Fe} \).](http://dx.doi.org/10.1051/jphyscol:1979244)
while ferromagnetism occurs in most of the concentration range, spin-glass behavior occurs in the samples with low Fe content ($x \leq 0.15$) /5/. These features are substantially different from those of crystalline Fe-Ni alloys /6/. Although low Fe concentration samples are not available for amorphous $(\text{Fe}_x\text{Ni}_{1-x})_8\text{B}_2\text{O}$, their behavior would be similar to that of other Fe-Ni glasses with similar Fe-Ni contents.

The average exchange interaction among Fe and Ni of $J_{\text{FeFe}} = 680$ K, $J_{\text{FeNi}} = 1.5 J_{\text{FeFe}}$ and $J_{\text{NiNi}} = 0$ have been determined using the results from a coherent potential calculation /7/. The very different values of $J_{\text{FeFe}}$ and $J_{\text{NiNi}}$ are clear from the concentration dependence of $T_C$. The larger value of $J_{\text{FeNi}}$ comes from the fact that the curve shown in figure 1 has a maximum in the mid-Fe-concentration range.

3.2. Magnetic hyperfine interaction. - The magnetic hyperfine spectra of $(\text{Fe}_x\text{Ni}_{1-x})_8\text{B}_2\text{O}$ at 4.2 K are shown in figure 2. The distributions of hyperfine fields $\langle P(H)\rangle$ contained in these spectra have been analysed using the Fourier series method developed by Window /7/. The reliability and the shortcomings of this method have been described elsewhere /9,10/.

![Magnetic hyperfine spectra and field distribution](image)

**Fig. 2**: Magnetic hyperfine spectra and field distribution $\langle P(H)\rangle$ of amorphous $(\text{Fe}_x\text{Ni}_{1-x})_8\text{B}_2\text{O}$ at 4.2 K.

Since the spectra are very symmetric about the centroid, we have assumed in these analyses a single average isomer shift and no effective quadrupole interaction. The $P(H)$ obtained from these spectra are quite structureless and slightly asymmetrical. For samples with decreasing Fe concentration, the $P(H)$ shifts to lower H values. The values of $H_{\text{peak}}$ (the peak of $P(H)$), $\langle H \rangle = \int P(H) \, dH$ [the average hyperfine field] and the average isomer shift determined are shown in figure 1 as a function of Fe content. The isomer shift values are relative to that of crystalline $\alpha$-Fe at 4.2 K. Both $H_{\text{peak}}$ and $\langle H \rangle$ increase monotonically with Fe content whereas the average isomer shift decreases with Fe content. Unlike the behavior of $T_C$, $H_{\text{peak}}$ and $\langle H \rangle$ show no maximum in the mid-Fe-concentration range. These features are also similar to those of other (Fe-Ni) metallic glasses /4,10/.

Of considerable interest is the value of $H_{\text{max}}$, the value at which $P(H)$ approaches zero. A number of $P(H)$ analyses of amorphous Fe-metalloid systems have indicated that at room temperature, $H_{\text{max}}$ is less than that of crystalline $\alpha$-Fe (330 kOe) /11/. This implies that no appreciable amount of Fe atoms could have hyperfine field values higher than that of $\alpha$-Fe. However, it appears that this is not the case for the saturation $P(H)$ measured near 0 K. As shown in figure 2, for the Fe-rich samples, $H_{\text{max}}$ is about 380 kOe; there are a noticeable amount of Fe atoms which have hyperfine fields higher than 340 kOe, the saturation value for $\alpha$-Fe. Previously, Bernas et al. /12/ have indicated that the conduction electron contribution to the hyperfine field is much less important in crystalline Fe-B interstitial compounds. The present results of a larger $H_{\text{max}}$ is consistent with this conclusion since the conduction electron contribution has an opposite sign to that of the core polarization.
References


