COMPARISON OF THE SHORT-RANGE ORDER OF AMORPHOUS AND CRYSTALLINE (Fe,Ni)B ALLYOS

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COMPARISON OF THE SHORT-RANGE ORDER OF AMORPHOUS AND CRYSTALLINE (Fe,Ni)B ALLOYS


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From a fundamental as well as a technological point of view the metallic glasses show attractive properties which are due to the amorphous structure. Physical properties which are sensitive for local configurations can provide valuable information on the nature of the short-range atomic arrangements. The chemical short-range order of ferromagnetic metallic glasses is reflected in the hyperfine field distribution $p(H)$ because of its sensitivity for the local environments. In a series of transition metal-metalloid systems with one magnetic constituent it was found /1/ that the average hyperfine field is proportional to the average magnetic moment of the magnetic component. It is well-known from comparisons between various intermetallic compounds that the magnetic moment is determined mainly by the number of nearest metalloid neighbours, that is the magnetic moment (or hyperfine field) distribution reflects mainly the distribution of the neighbouring metalloid atoms.

It has been shown /2/ that in the crystallization of Fe$_{1-x}$B$_x$ (0.15 ≤ $x$ ≤ 0.25) glasses the Fe$_{75}$B$_{25}$ composition plays a prominent role. During the crystallization of these glasses two processes were observed, namely: 1, a precipitation of α-Fe until the composition of the remaining glass reaches the Fe$_{75}$B$_{25}$ composition and 2, the glass with this composition transforms into the metastable Fe$_3$B intermetallic compound. The iron $p(H)$ distribution measured by Mössbauer method in the amorphous Fe$_{75}$B$_{25}$ alloy could be satisfactorily described /3/ with the assumption that its local environments are similar to those in the Fe$_3$B compound.

These results suggested a more general model according to which /3/ the complex structure of metallic glasses at arbitrary composition is determined by two dominant contributions, namely

i, structural disorder, and
ii, chemical disorder.

In this terminology structural disorder means the local distortion of the corresponding intermetallic compound (in the above case: TM$_{75}$M$_{25}$) which can be characterized by a Gaussian broadening of the lattice parameter and consequently also of the hyperfine field around the crystalline values. Chemical disorder results from deviations from this special composition which cause distortion of the "ideal" amorphous structure (that of the TM$_{75}$M$_{25}$ glass) and can be described in analogy to the case of non-stoichiometric intermetallic compounds.

In this paper we report the preliminary results of the first systematic investigation of the effect of structural disorder in metallic glasses. The amorphous (Fe$_{1-x}$Ni$_x$)$_{75}$B$_{25}$ alloys are especially suitable for this study because they crystallize into a single phase. The X-ray controlled amorphous samples were prepared at the Central Research Institute for Physics, Budapest by quenching onto the external surface of a rotating copper disk. The Mössbauer measurements were evaluated with the method of Ref. 4. According to X-ray evidences the samples between $x = 0$ and 0.5 crystallize into the metastable tetragonal Fe$_3$B structure isostructural to Fe$_3$P. The structure has three crystallographically inequivalent iron sites with 2B, 3B and 4B nearest neighbours.

Fig. 1 shows the concentration dependence of the average hyperfine field for the amorphous and crystalline alloys. It is important to note that $R_{Fe}$ decreases between $x = 0$ and 0.5 about 10% but the amorphous and crystalline values agree with each other within 1-2%. This suggests strong similarities in the short-range order of these glasses and metastable crystalline compounds.

Fig. 2 shows the temperature dependence of the
Fig. 1. Average iron hyperfine field extrapolated to 0 K in amorphous and crystalline \((\text{Fe}_{1-x}\text{Ni}_x)_{75}\text{B}_{25}\) alloys. The difference between the magnetization curves of the amorphous and crystalline states is smaller than 5% and the magnetization in both states decreases much faster with temperature than in metallic iron. This shows that the structural disorder has a minor effect on the shape of the magnetization curve and that the high metalloid content is responsible for the rather fast decrease of magnetization in these materials. This conclusion contradicts a view which can be found in the literature \cite{5} and was obtained from an incorrect comparison of the magnetization curves of metallic iron and metallic glasses.

Fig. 3 shows significant differences between the \(p(H)\) of \(\text{Fe}_{75}\text{B}_{25}\) and \((\text{Fe}_{0.5}\text{Ni}_{0.5})_{75}\text{B}_{25}\). It is very remarkable that the calculated curve in Fig. 3b (with no adjusted parameter) reproduces reasonably well the narrowing of \(p(H)\) (in this calculation the crystalline hyperfine field values were experimentally determined from the cr. \((\text{Fe}_{0.5}\text{Ni}_{0.5})_{75}\text{B}_{25}\) compound). This again strongly supports the assumption that in the investigated cases the short-range order of the glass and crystalline compound is nearly identical.

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