

THE MICROHARDNESS OF TRANSITION METAL-METALLOID GLASSES

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Introduction

Recently developed rapid quenching techniques made possible the production of amorphous alloys in a ribbon form of practically unlimited length and allowed to study easier their elastic and plastic properties. It has been found that the magnetic properties of Fe-Ni-base glasses are superior to those of the conventional crystalline Fe-Ni alloy, but for practical applications it is very important to use materials with good magnetic as well as mechanical properties. According to above we started to investigate microhardness, H_v , of Fe-Ni base glasses. The role of metalloid element(s) and compositional trends of microhardness were examined. Furthermore, we tried to connect the similarity in behaviour between plastic and magnetic properties. In addition, the changes of H_v during the annealing were investigated too.

Experimental

The samples of Fe-Ni-base metallic glasses were obtained in the form of long ribbons and were prepared from the master alloys of predetermined concentrations by the use of a melt spinning device. Isochronal annealing in vacuum was carried out for 30 min. in steps of 50 °C over the temperature range 50-1000 °C. After each annealing step samples were air-cooled to room temperature in order to follow microhardness changes during heat treatment. For the purpose of microhardness measurement they were glued on to a glass slide with shiny face up. H_v values were obtained using Zeiss (Jena) equipment with a 136⁰ diamond pyramid indenter and 100 ponds load. On each sample more than 20 indentations were made and the standard deviation was near to 7% of the mean value. The problem of the choice of indenter load was already discussed /1/. Here, we investigated the influence of the sample thickness,

t, on H_V . In Fig. 1 are shown the results for $Fe_{40}Ni_{40}B_{20}$ amorphous alloy and for three different values of applied load. It is visible that in the explored thickness range (20-50 μm) the sample thickness has no significant influence on the hardness values.

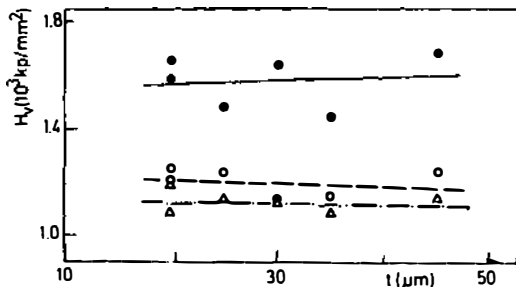


Fig. 1 Variation in microhardness with the sample thickness of $Fe_{40}Ni_{40}B_{20}$ metallic glass and the indenter load: 50 p- ●, 100 p- ○ and 160 p- △. The lines in Fig are obtained by the use the linear least square fit to the experimental data.

Results and Discussion

It was already suggested /2/ that the metalloïd element(s) has a profound influence on the strength and stiffness of the transition metal/metalloïd (TM/M) glasses. Furthermore, M.Naka et al. /3/ investigated the effects of alloying elements on the hardness as a measure of atomic bonding force and crystallization temperature of amorphous iron-base alloys $Fe_{80-x}M_xP_{13}C_7$ (M=Ti, V,Cr,Mn,Co,Ni and Cu). They showed that the increase of the averaged outer electron concentration of the metallic atoms, e/a , i. e. the increase of the d-electron concentration weakens the strengths of the bonds between transition metal and metalloïd atoms. These bonds are formed by the overlap of the s-p hybrid orbitals of P and B metalloïds and s-p-d orbitals of transition elements and play the dominant role in determining the properties

of TM/M alloys. Our results for H_v of $Fe_xNi_{80-x}P_{14}B_6$ and $Fe_xNi_{80-x}B_{20}$ series as a function of e/a and of transition metal composition are shown in Fig. 2a.

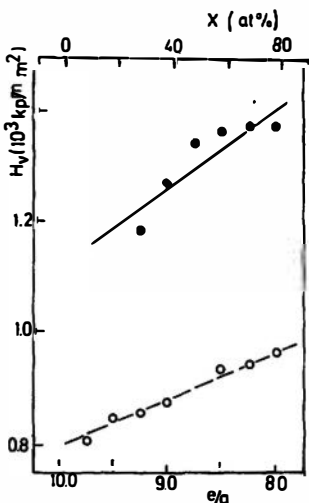


Fig. 2a. Microhardness plotted against the averaged outer electron concentration of the metallic atoms e/a and the transition metal composition x : $Fe_xNi_{80-x}P_{14}B_6$ -○-, $Fe_xNi_{80-x}B_{20}$ -●-.

It can be seen that changing the metalloids content from $P_{14}B_6$ to B_{20} leads to marked enhancement of H_v values. On the other hand, if one replaces Fe with Ni while retaining the same content of metalloids, relatively modest variation in H_v is observed. These results show that the metal-metalloid bonds are of primary importance in determining some of the properties of TM/M glasses and confirm the conclusion of Naka et al./3/ about the effect of d-electron concentration on these bonds. The influence of metalloids extends also to their magnetic properties. It is known from magnetic measurements that $Fe_xNi_{80-x}B_{20}$ amorphous alloys exhibit both higher Curie temperature and higher saturation induction than $Fe_xNi_{80-x}P_{14}B_6$ alloys /1/. Also, the influence of the magnetic interactions on the elastic properties is recently reviewed /4/. Moreover, the compositional variation of the specific elastic modulus, E/ρ , for $(Fe,Co)_{80}B_{20}$ and $(Fe,Ni)_{80}B_{20}$ has been reported /5/. It was found that E/ρ behaves as if magnetoelastic effects stiffening of the glassy alloys is proporti-

onal to the magnetization squared. Taking into account the observed correlation between plastic and elastic properties of TM/M glasses /6/ we tried to correlate the behaviour of H_V to $\langle s \rangle^2$ /1/. In Fig. 2b we show our H_V data vs $\langle s \rangle^2$ i.e. assuming the dependence: $H_V = A + B \langle s \rangle^2$. On the basis of Fig. 2a and 2b one cannot say whether e/a or $\langle s \rangle^2$ variation determines H_V . Both assumptions explain about equally well the microhardness variation. We note however that the continuous decrease in H_V of $Fe_xNi_{80-x}P_{14}B_6$ alloys even for $x \leq 20$ (where $\langle s \rangle^2 = 0$ at room temperature) seem to favour the first mentioned model.

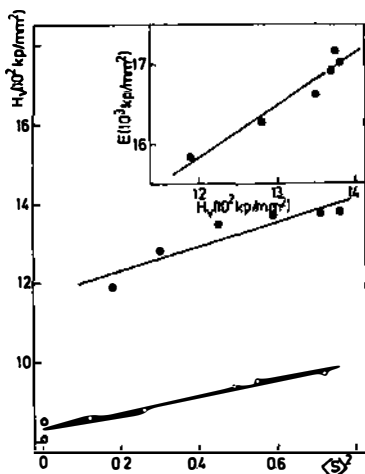


Fig. 2b. H_V values vs $\langle s \rangle^2$ for $Fe_xNi_{80-x}P_{14}B_6-O$ and $Fe_xNi_{80-x}B_{20}$. Full lines are obtained from equation: $H_V = A + B \langle s \rangle^2$ by using the linear least square method. In the inset E vs H_V .

The results of our investigation of changes in H_V on isochronal annealing (50- 1000 °C) of $Fe_{40}Ni_{40}B_{20}$ and $Fe_{40}Ni_{40}P_{14}B_6$ are shown in Fig. 3. The idea was to see the influence of the metalloid on the annealing morphology. The results for $Fe_{40}Ni_{40}B_{20}$ alloy agree well with those from our earlier work /7/ and therefore the same explanation is valid. The H_V behaviour of $Fe_{40}Ni_{40}P_{14}B_6$ alloy is similar to that of $Fe_{40}Ni_{40}B_{20}$ and can be divided in three significant regions. In the first region (50-400 °C) the variation in H_V is due to structural relaxation of still amorph-

ous alloy. The onset of crystallization and the formation of small crystallites of metastable phases leads to a strong increase in H_V . The subsequent change in the volume ratios of present phases gives a strong maximum in H_V centered around 500°C.

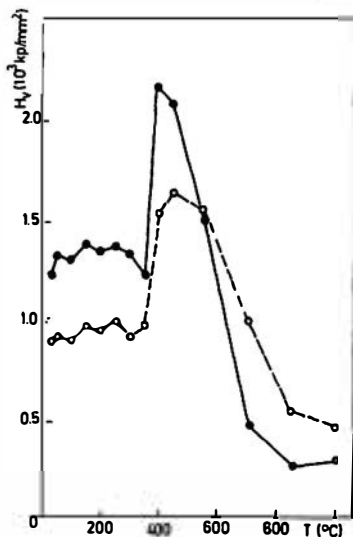


Fig. 3. Microhardness changes during isochronal annealing of metallic glasses: $Fe_{40}Ni_{40}B_{20}$ - O , $Fe_{40}Ni_{40}P_{14}B_6$ - \circ .

Finally, the appearance of the stable phases leads to a decrease in H_V in the range $600^\circ C \leq T_a \leq 1000^\circ C$. This decrease is considerably slower in $Fe_{40}Ni_{40}P_{14}B_6$ alloy than in $Fe_{40}Ni_{40}B_{20}$ one which is probably due to more complex crystallization sequence in this system. We also note that the final H_V values ($T_a \approx 1000^\circ C$) are higher for $Fe_{40}Ni_{40}P_{14}B_6$ alloy which indicates that the number of crystalline phases and their volume ratios determine H_V of crystallized samples. Further work on the change of H_V in several alloys from both alloy systems is now in progress.

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