A PRELIMINARY STUDY OF EMBRITTLEMENT OF Co–BASED AMORPHOUS ALLOYS BY POSITRON ANNIHILATION

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ABSTRACT

Measurements of the Doppler broadening *S*–lineshape parameter of positron annihilation and brittleness have been performed for two Co–based amorphous alloy prior to crystallization. It is shown that the brittleness is related to the *S*–parameter, that is, microdefects may be one of the important factors affecting the embrittlement of the Co–based amorphous alloys.

Keywords: Positron annihilation Amorphous alloy

1 INTRODUCTION

Co–based amorphous alloy is one of soft–magnetic materials of technical interest. It has been found, however, that there exists a trouble of embrittlement in practical uses of the alloy, especially subjected to annealing at higher temperature. As we all know, the embrittlement of amorphous alloys, whether Co–based or not, is one of the most complex subject that are now being investigated, both theoretically and technologically. The understanding of its nature perhaps needs to be explored by the combination of many different techniques. In addition, as far as most of the experiments by positron annihilation method for amorphous alloys up to now is concerned, it is difficult to use positron annihilation parameters directly to interpret macroscopic properties. Have the positron annihilation parameters little interconnection to the macroscopic properties, as is often implied? The only attempt of the present paper is to study if the embrittlement of the Co–based amorphous alloys has anything to do with the parameters of positron annihilation, or rather, if positron annihilation technique could offer some valuable information for explaining the embrittlement of Co–based amorphous alloys. And in literature, there were few reports on this respect[1].

For characterization of the alloys to be tested, differential thermal analysis and X–ray diffraction techniques were used as well.

2 EXPERIMENTAL PROCEDURE AND RESULT DISCUSSION

Two Co–based amorphous alloys were prepared. The alloying elements were melted in a mid–frequency induction furnace to yield master alloys, which were made into the form of 0.03 mm thick ribbons by rapid quenching from the melt using the melt spinning technique under carefully controlled conditions. The compositions of two alloys are: $Co_{64.8}Fe_{7.5}Si_{4.3}B_{22.9}Mo_{0.5}$ (*A*), $Co_{66.0}Fe_{4.0}Si_{9.0}B_{14.0}Mn_{7.0}$ (*B*).

The examination of the as–quenched ribbons by the differential thermal analysis at a heating rate of 20°C/min and X–ray diffraction at the $k_{\alpha 1}$ of Co–target indicated that the first exothermic peak (i.e.crystallization) appears at 512°C for alloy *A* and at 533°C for alloy *B*, and all the X–ray broad diffraction peaks are of the usual patterns of amorphous state before their crystallization.

The samples for the measurements of brittleness and Doppler broadening were cut from the as–quenched alloys and had gone through annealing separately at the different temperatures that are below their crystallization temperatures.

The brittleness, or toughness, of the as–quenched and annealed ribbons was checked up in terms of a simple method of bend–breaking off. For the as–quenched samples, alloy *A* is very good in toughness and not broken off even when it is in folding. Beside *A*, *B* is worse and broken off while it is folded; In the annealed specimens, alloy *A* starts to exhibit brittle (broken off upon folding) from 300°C and is getting worse with the increase of annealing temperature. *B* is already very brittle (broken off as it is bent to the angle of less than 90°) at 200°C.

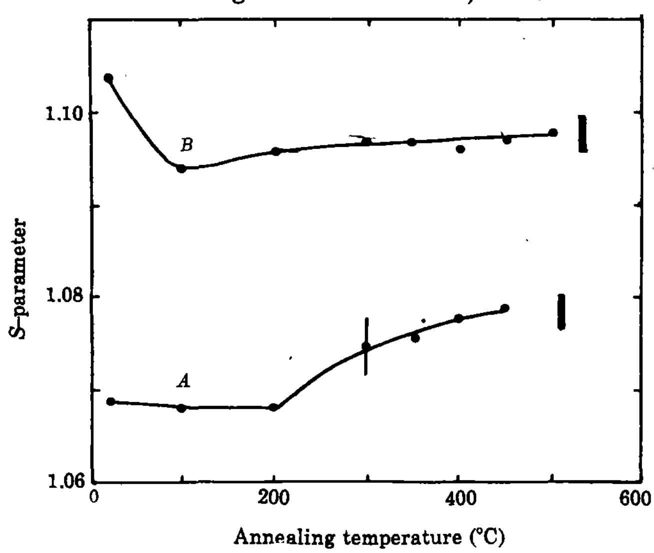

Fig.1 Variation of the S–lineshape parameter with the annealing temperature for $Co_{64.8}Fe_{7.5}Si_{4.3}B_{22.9}Mo_{0.5}$ (*A*) and $Co_{66.0}Fe_{4.0}Si_{9.0}B_{14.0}Mn_{7.0}$ (*B*)

The thick and thin bars show the crystallization temperature and the error of the *S*–parameter, respectively

Positron annihilation measurements were performed by means of an ordinary Doppler broadening spectrometer, the details of which have been described elsewhere[2]. 511 keV γ –peak was characterized by the *S*–lineshape parameter defined as a ratio of counts in a narrow central portion to those in the wings of the peak. Each of specimens, which have been used for making the measurements of the brittleness, consisted of two stacks of ribbons with a positron source of $^{22}NaCl$ sandwiched between them. Six pieces of ribbons were in each stack, so that the total thickness was sufficient to deplete the energies even for the most energetic positrons within the specimens. The measured *S*–lineshape parameters are shown in Figure 1 as a function of the annealing temperature for the two amorphous alloys.

In order to varify the reproducibility of the results, a second experiment repeating the above procedure of sampling, annealing, and measuring was done and gave the same results as the first, except some negligible fluctuations in crystallization temperature and *S*–parameter. Hence, the present experiments are surely not accidental.

By comparing the measurements of the brittleness with the *S*–parameters, it could be found that the two are mutually dependent in a large degree. The as–quenched alloy *B* is more brittle than *A*, correspondingly, the *S*–parameter of the former is bigger than that of the latter; The annealed alloy *A* becomes more brittle from 300°C, and at that very temperature its *S*–parameters have come to go up. In other words, the as–quenched alloy *B* can be more brittle than *A* because in *B* more intrinsic microdefects were formed in the process of quenching than in *A*; The annealed alloy *A* is getting more brittle from 300°C on account of new microdefects (or non uniformity) being developed during the annealing. What types the intrinsic and the new microdefects are and whether the two are the same or not, however, could not be determined at the moment[3].

Next, it is apparent that the tendencies for the *S*–parameters of curve *A* and *B* in the Figure 1 varying with the annealing temperatures are different from each other. Curve *A* is level and increases with *S*–parameter. And curve *B* goes down from the vary beginning and then gets flat, meaning that its microdefects are reduced by the annealing. Obviously, by means of microdefects only one can not explain away why alloy *B* is more brittle. Some kinds of brittle clusters or some unknowns, produced due to the relaxation of atoms, may result in severe embrittlement.

According to the experiments mentioned above, as a matter of fact, a further inference could be drawn that the compositions' contribution to embrittlement is of paramount importance. The two alloys here were prepared with the same technical process, and yet alloy *B* gives a far higher value of the *S*–parameter and is more brittle than alloy *A*. This may be attributed to the differences between the compositions of the two alloys.

3 CONCLUSION

The two amorphous alloys of $Co_{64.8}Fe_{7.5}Si_{4.3}B_{22.9}Mo_{0.5}$, (*A*) and $Co_{66.0}Fe_{4.0}Si_{9.0}B_{11.0}Mn_{7.0}$

(B) prior to crystallization have been studied through the use of the measurements of brittleness and Doppler broadening complemented with differential thermal analysis and X–ray diffraction techniques. The results show that the embrittlement of the alloys is related, in a certain degree, to the *S*–parameter: The macroscopic property and the positron data are not completely independent. Although the factors affecting the embrittlement are complex in such complicated engineering materials, the function of microdefects, or non–uniformity, should not be underestimated, at least for the study of the present Co–based amorphous alloys.

REFERENCES

[1] Janot Par Chr, George B, Teirlinck D *et al. Phil Maga A*, 1983, 47:301.
[2] Wang J C, Yang S W. *Scripta Met*, 1989, 23:363.
[3] Dorikens–Vanpraet L, Doriken M, Segers D eds. Positron annihilation. Singapore: World Scientific, 1988: 392.