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Influence of Plastic Deformation on Devitrification of $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ Amorphous Alloy

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The method of thermogravimetry in external magnetic field was modified using square wave alternate magnetic field for an estimation of the temperature dependence of the magnetization. This method was used for the study of influence of plastic deformation of the amorphous alloy $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ on the structural changes.

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1. Introduction

The intensive plastic deformation localized into adiabatic shear bands causes the intensive heating and structural changes in amorphous alloys. During the heating the temperature inside shear bands overcomes the glass transition temperature. This was confirmed by the examination of fracture surfaces [1, 2] or by direct measurement of the temperature near the shear bands [3]. Intensive plastic deformation stored into the amorphous structure by long time milling tends to the partial or total crystallization of metallic glasses [4, 5]. During milling the mechanical alloying processes can cause the change of chemical composition of the milled powder. It was reported that this effect was responsible for the crystallization of the amorphous alloy during long time milling [6]. Therefore the study of the influence of small plastic deformation on the structure of amorphous alloys can contribute to better understanding the deformation processes in amorphous alloys.

The widely used methods of thermal analysis are useful for the thermal stability study. Thermogravimetry in external inhomogeneous magnetic field can be used for the estimation of magnetic transition. There are several effects, acting during thermogravimetric experiments: the buoyancy effect, the increase of mass due to the corrosion of the sample, the decomposition of sample, the instability of carrying gas flow. We have modified this thermomagnetic method using the modulated magnetic field. This enables us to extract the magnetic contribution to the measured weight changes in thermomagnetometry.

2. Experimental

The Finemet type ($Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$) amorphous ribbon was deformed by repeated shot peening. The peening was carried out by application of 500 impactions with the hammer, weighting 100 g, which had a mounted tip with the diameter of 1 mm. The adapted commercial thermogravimeter SETARAM TGDTA92 under continuous heating in modulated magnetic field was used for the thermomagnetic characterization of the samples. The chosen period of the field change (60 s) was sufficient to enable the stabilization of the weight. The temperature modulated DSC Q2000 TA Instruments was used for the calorimetric study of Curie transition in the amorphous alloy.

3. Results and discussion

The measured weight changes TG_{mg} of the deformed amorphous alloys during the heating in modulated magnetic field are shown in Fig. 1. For undeformed samples in as quenched state the similar form of the curves is observed. The magnetization of the samples, characterized by the amplitude of TG signal during heating of the sample up to the Curie transition, decreases. The contribution of the magnetic force is present at temperatures above 500 °C, when the sample crystallizes. At higher temperatures the magnetic signal decreases due to reaching of the Curie transition in the crystalline phase. In the temperature interval above the Curie temperature of the amorphous phase and below the crystallization temperature no magnetic contribution to the TG signal was observed. Because the Curie temperature of nanocrystalline Fe lies above 600 °C, the absence of magnetic force at temperatures below the crystallization implies that no presence of crystalline phase induced by deformation was observed.

For a more detailed description of the differences in the amorphous phase structure of deformed and undeformed samples, the method of modulated Differential Scanning Calorimetry (DSC) was used. The average heating rate was 10 °C/min. The period and the amplitude of the temperature modulation were 60 s and 1 °C, respectively.

This method gives the possibility to separate the reversible and irreversible contribution to the thermal effects observed by DSC. The separated reversible and irreversible contribution to the flow for the as quenched state and for samples during the subsequent heating can be seen in Fig. 2. Due to the structural relaxation the

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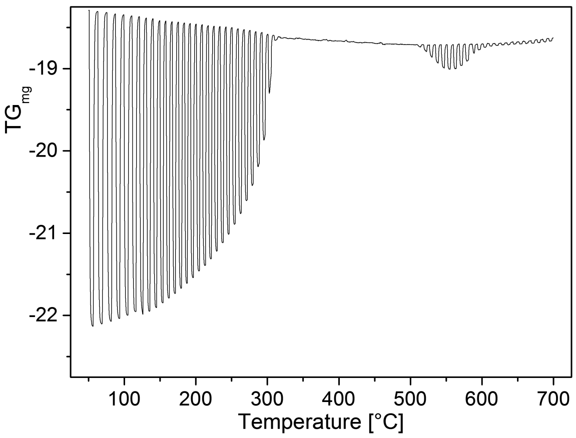

Fig. 1. Temperature dependence of weight changes of the deformed alloy in modulated external magnetic field.

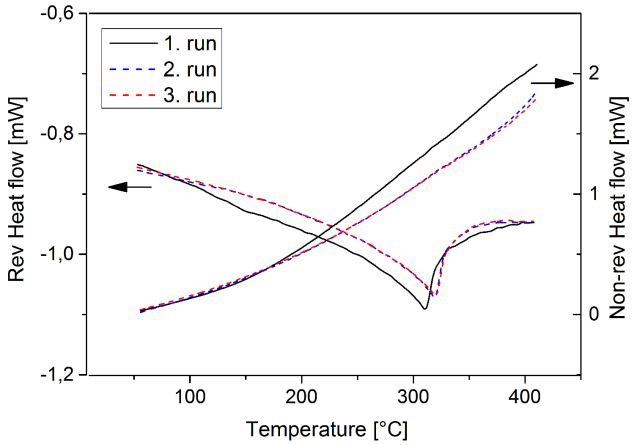

Fig. 2. Reversible and irreversible contribution to the heat flow of the undeformed sample of Finemet alloy during the repeated heating.

first run differs from the second and the third ones in the reversible and irreversible components of the heat flow. The sharp peak present in reversible heat flow traces, corresponds to the Curie transition. It is shown that the structural relaxation leads to shifting of the Curie transition temperature from 313.7 °C to the value of 321.8 °C.

The reversible part of the heat flow for the undeformed and deformed samples is shown in Fig. 3. It can be seen, that the plastic deformation causes the broadening of the magnetic contribution to the heat flow. A small decrease in the temperature of the peak maximum for the deformed sample is present. During the repeated heating runs of the deformed samples, the similar tendency is observed. The Curie temperature is shifted from 314.6 °C at the first heating run, to 322.6 °C at the third one.

It was shown that the repeated impactions modify the form of thin ribbons. The shallow pits are formed via the creation of radial and tangential shear bands. Repeating of impactions leads to creation of more complex cross-linked shear band morphology [7, 8].

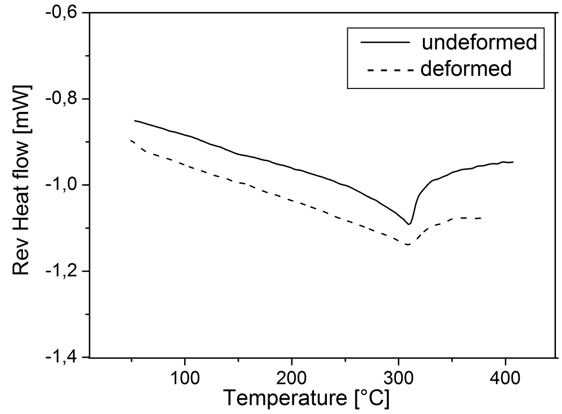

Fig. 3. Reversible heat flow component for the first run of the undeformed and deformed samples.

4. Conclusion

Application of the modulated magnetic field during the thermogravimetry enables to separate the buoyancy and the sample mass stability problems. Due to the plastic deformation introduced by repeated shot peening, the shear bands on the ribbon surface have the complex morphology. The introduced plastic deformation causes changes in the magnetization in the amorphous state and broadens the interval of Curie transition.

Acknowledgments

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