NOVEL AMORPHOUS Fe-Zr-Si(Cu) BORON-FREE ALLOYS

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Amorphous and nanocrystalline Fe-based alloys have been studied extensively for recent years due to their excellent soft magnetic properties. Such alloys are very attractive for technical applications. Until now all known technically important alloys contain boron addition that increases glass forming ability and improves thermal stability of the amorphous alloys. However, boron is a relatively expensive element, therefore it would be of significant economical benefit to replace boron by a cheaper glass forming element, e.g., Si.

It is expected that amorphous Fe-Zr-Si(Cu) alloys revealing excellent soft magnetic properties can be prepared in a fairly wide composition range by the melt quenching technique.

The aim of the present study is the preparation and structural characterization of the novel amorphous $Fe_{80}(Zr_xSi_{20-x-y})Cu_y$ (x = 6 –10 at. %, y = 0, 1 at. %) boron-free alloys that will show soft magnetic properties comparable with the conventional iron-based amorphous rapidly solidified materials. The amorphous Fe-Zr-Si(Cu) alloys have been prepared in Ar atmosphere by the melt quenching technique in the form of ribbons about 1 mm wide and 20 μm thick. The Mössbauer spectroscopy, x-ray diffraction (XRD) and differential scanning calorimetry (DSC) were used in the characterization of the melt quenched alloys. The fully amorphous alloys, as determined by XRD and Mössbauer measurements, were obtained for x = 6, 7, 9 or 10, and y = 0, 1 with the highest cooling rate used, equivalent to the linear velocity at the wheel of 55 m/s in the single roller melt spinning machine.

The Mössbauer spectra of the as-quenched ribbons with $6 \leq x \leq 10$ at. % are composed of the broadened sextets characteristic for the ferromagnetic amorphous alloys. The hyperfine field distributions were calculated from the transmission spectra. No traces of the crystalline fractions were detected. The XRD patterns recorded for the amorphous alloys consist of only one broad peak characteristic for the amorphous phase.

The DSC measurements at 20K/min revealed that the onset temperatures of crystallization of the amorphous Fe-Zr-Si(Cu) alloys are rather high. In the available temperature range (50 – 720^{o}C) the DSC curves of the amorphous alloys revealed one or two crystallization peaks, depending on the alloy composition. For several amorphous alloys studied the second crystallization step was expected at temperatures exceeding the available temperature range for DSC studies.

The soft magnetic properties of amorphous Fe-Zr-Si(Cu) alloys have been studied by the specialized “rf-Mössbauer” technique in which the spectra were recorded during exposure of the samples to the rf field of 0 to 20 Oe at about 61 MHz. The complete rf-collapse effect was observed. This study was accompanied by the conventional measurements of quasistatic hysteresis loops. Typical coercive fields determined for amorphous Fe-Zr-Si(Cu) alloys varied from 24 A/m to about 100 A/m, depending on alloy composition. Such coercivities correspond well to those of the conventional boron-containing soft magnetic amorphous Fe-based alloys. The coercivity was significantly larger for the partially nanocrystallized alloys.

It is concluded that the boron-free amorphous Fe-Zr-Si(Cu) alloys studied here (with $6 \leq x \leq 10$ at. %, y=0, 1 at. %) are good candidates for practical applications as the economical soft magnetic materials.

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