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DOI: 10.1017/S143192760606452X

Microsc Microanal 12(Supp 2), 2006

Medium Range Order in $Zr_{70}Pd_{30}$ Metallic Glass Under Ion Irradiation.

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Metallic glasses have long been considered as robust materials for radiation fields[1], and there has been a revived interest recently in Zr-based metallic glasses for fusion reactors applications. The radiation resistance of such materials is thought to stem from the icosahedral short range order (ISRO) that is frozen in from the melt and which can sustain radiation-induced defects more readily than other types of local ordering.[2] Zr-based amorphous alloys have also been used to elucidate the dependence of the devitrification pathway of the material on the preparation method.[3] Those studies have attacked the fundamental question of whether clusters with ISRO are obtained solely from the melt or are promoted by the materials' composition. The work described herein examines the effect of ion irradiation on the structure of $Zr_{70}Pd_{30}$ metallic glass prepared by melt spinning using Fluctuation Electron Microscopy (FEM), aiming to provide a direct test of the resilience of the structure to radiation. Also, since ion irradiation offers the opportunity to modify structure without making large changes to composition this study also contributes to the understanding of the relative importance of preparation and composition in obtaining ISRO and the subsequent formation of the meta-stable quasi-crystalline phase.

Samples were prepared for the transmission electron microscope (TEM) by thinning the wheel side of the melt-spun $Zr_{70}Pd_{30}$ ribbons to electron transparency using single-jet electro-polishing. The TEM samples were irradiated *in situ* and monitored with imaging and diffraction using the IVEM-Tandem facility at Argonne National Laboratory. The advantage of irradiating thin foils is the ability to control precisely the ion interactions within the volume probed by the subsequent TEM analyses. 500 keV Kr^+ ions were employed, giving rise to an average deposited noble gas ion concentration of 0.02 at. % for the highest dose of 1×10^{15} Kr^+/cm^2. This concentration was estimated using a Monte Carlo simulation[4] to calculate the distribution of ions in the material and the measured foil thickness. These simulations suggest that both the electronic energy loss and nuclear stopping contribute appreciably within the thickness of the sample. We note that ion species and energy may be tuned to reduce implantation and to isolate the effects of electronic and nuclear stopping. The irradiations were performed at room temperature, with the ion flux limited to 6.25×10^{11} Kr^+/cm^2s to curtail beam heating effects. The microscope gun valve was closed during irradiation to prevent effects arising from dual irradiation with ion and electron beams. Subsequent to irradiation the samples were removed to a Jeol JEM-4000 EXII (200kV) for FEM.

Figure 1 a) displays a radial profile of the scattered electron intensity as a function of ion dose. The diffracted intensity corresponds well to previous findings from both x-ray and electron diffraction.[5][6] As can be seen the material remains amorphous for all of the doses employed. The peaks in the diffracted intensity occur at the same wave vector irrespective of ion dose. There is a slight broadening of the first diffracted peak that may indicate atomic re-arrangements and defect accumulation.[7] More striking are the changes to the medium range order of the material as seen in the FEM results shown in Figure 1 b). The FEM plot from the sample irradiated with 5×10^{14} Kr^+/cm^2 is within error of the FEM trace from the virgin sample. In contrast the magnitude of the first peak in the FEM plot from the sample irradiated with 1×10^{15} Kr^{+}/cm^{2} has increased significantly. This suggests that subject to a threshold dose the medium range order in $Zr_{70}Pd_{30}$ is increased due to ion irradiation. Intensive simulation would be required to identify this increase in medium range order with an increase in the number of clusters possessing a particular SRO. It is clear that this experiment contributes at several levels to the lively discourse on Zr-based metallic glasses.

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[9] This work was supported in part by the U.S. DoE under BES-MS W-31-109-Eng-38 at ANL

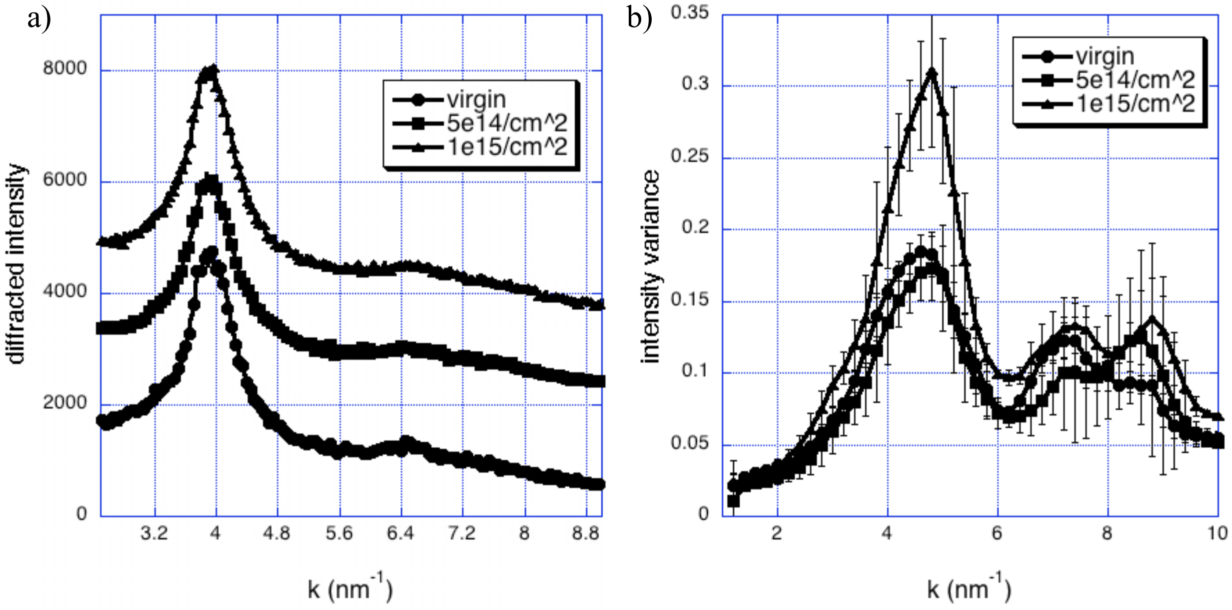

Fig. 1. a) Radial profile of scattered electron intensity. The samples remained amorphous at the doses used in this study. b) FEM measurements showing that after a threshold dose is surpassed there is a significant increase in the degree of medium range ordering.