

# Self-Diffusion of Iron in Amorphous Fe<sub>67</sub>Zr<sub>33</sub> Multilayers Measured with Neutron Reflectometry

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Fe-Zr isotopic multilayers samples with the structure Si/[FeZr(9nm)<sup>57</sup>FeZr(5nm)]<sub>x20</sub> have been prepared by co-sputtering of Fe and Zr using magnetron sputtering. In the as-deposited state the film has been found to be amorphous. The self-diffusion measurements on the multilayers have been done using neutron reflectivity at AMOR and TOPSI after annealing the multilayers below nanocrystallization temperature to achieve a constant diffusion length at each temperature. It has been found that the diffusivity at different temperatures follows the relation  $D=D_0 \exp(-q/KT)$  giving an Arrhenius type behaviour and the measured pre-exponential factor  $D_0$  and the activation energy  $q$  are:  $D_0 = 2 \times 10^{-17 \pm 1} \text{ m}^2 \text{ s}^{-1}$ ;  $q = 0.4 \pm 0.1 \text{ eV}$ . The activation energy for the present system has been found to be considerably low as compared to that of bulk diffusion in similar alloy.

Diffusion in amorphous alloys has been of great interest, as changes in the structure of these alloys and their relation to the physical and mechanical properties are of primary interest from the point of view of their technological application and stability against external environment. Despite extensive studies in recent years [1,2,3], the underlying mechanism of diffusion in amorphous alloys has not yet been understood properly.

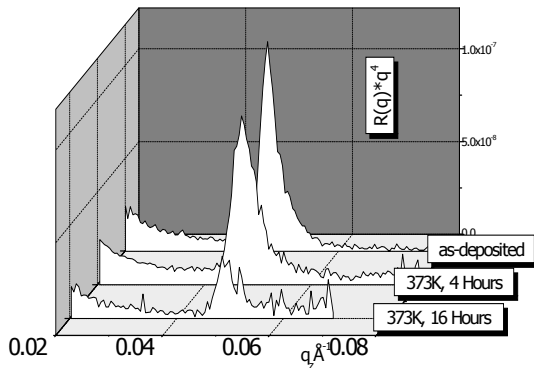


Fig. 1: Decay of Bragg peak intensity at 373 K for different annealing times.

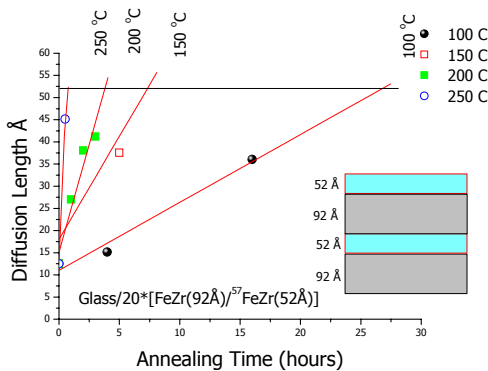


Fig.2 : Variation of diffusion length as a function of annealing temperature and time.

In the present study, self-diffusion measurements of iron in amorphous Fe<sub>67</sub>Zr<sub>33</sub> isotopic multilayers using neutron

reflectivity are reported. Neutron reflectivity is a technique, which can measure (self) diffusion lengths of the order of a fraction of a nm, which is about an order of magnitude smaller as compared to conventional techniques e.g. secondary ion mass spectroscopy depth profiling.

The thermal annealing of the as-deposited film shows that up to an annealing temperature of 573K, the film remains amorphous and after annealing at 673K the film becomes nanocrystalline with an average grain size equal to 6nm. The self-diffusion measurements using neutron reflectivity in the multilayers have been done after annealing the multilayers below nanocrystallization temperature to achieve a constant diffusion length at each temperature by monitoring the decay of intensity at the Bragg peak arising due to isotopic periodicity.

A similar decay of reflectivity at the Bragg peak has been obtained at four different temperatures (373K,423K,473K and 523K, for different annealing times) and the diffusivity has been obtained. It has been found that the diffusivity at different temperatures follows Arrhenius type behaviour and the pre-exponential factor  $D_0$  and the activation energy  $q$  are:  $D_0 = 2 \times 10^{-17 \pm 1} \text{ m}^2 \text{ s}^{-1}$ ;  $q = 0.42 \pm 0.1 \text{ eV}$ . The activation energy and the pre-factor in the present case have been found to be significantly small as compared with the bulk diffusion at high temperature. As the activation energies of the vacancy-related diffusion processes are  $\sim 1.5 \text{ eV}$ [1], it has been suggested that in the present case diffusion is mainly contributed by point defect concentration and their mobility. In order to determine the diffusion mechanism in the alloy, measurements of diffusion with the applied pressure are being done now.

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