Small-Angle Scattering from Neutron-Irradiated Amorphous Pd$_{80}$Si$_{20}$

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Small-angle scattering intensities were observed for amorphous Pd$_{80}$Si$_{20}$, which was irradiated by fast neutrons to a fluence of $5 \times 10^{20}$ neutrons cm$^{-2}$. A broad hump was observed at $2 \sin \theta/\lambda = 0.05$ Å$^{-1}$. The structural inhomogeneities produced by the neutron irradiation are discussed with the aid of the results of wide-angle scattering measurements [Doi, Kayano & Masumoto (1977). Appl. Phys. Lett. 30, 421-422].

Foils of amorphous Pd$_{80}$Si$_{20}$, prepared by the filamentary casting method (Masumoto & Maddin, 1971), were irradiated by fast neutrons, and their structural changes were investigated by both wide-angle and small-angle X-ray scattering. The specimens, rectangular foils 10 x 2.0 x 0.05 mm, were irradiated in the Japan Material Testing Reactor with fast neutrons (> 1 MeV) to a fluence of $5 \times 10^{20}$ neutrons cm$^{-2}$. As no temperature control was provided, the foils may have been heated to about 150°C during the irradiation.

The wide-angle X-ray scattering with Cu Ka$_1$ in the range $s = 2 \sin \theta/\lambda = 0.1 - 1.2$ Å$^{-1}$ has revealed that the distribution of scattered intensity is hardly altered by the irradiation except for $s < 0.4$ Å$^{-1}$, i.e. in the small-angle region and at the leading edge of the first halo having its maximum at $s = 0.45$ Å$^{-1}$ (Doi, Kayano & Masumoto, 1977). These observations suggest that neutron irradiation as heavy as $10^{20}$ neutrons cm$^{-2}$ only affects the atomic arrangements over distances longer than several ångströms, those over shorter distances being hardly changed after the irradiation (Fig. 1).

In an attempt to understand the nature of the long-range structural changes, small-angle regions ($s = 0.001 - 0.10$ Å$^{-1}$) were explored with a conventional three-slit small-angle diffractometer having a FWHM of 0.0006 Å$^{-1}$ for the direct beam. Cu radiation was used and the scattered rays were recorded by a scintillator counter with pulse-height discrimination. Photon counting and detector drive were performed in a stepwise manner. Parasitic scattering was corrected for by blank runs of intensity measurements. Fig. 2 shows the results. Full circles and the continuous curve refer to the irradiated sample, and open circles and the dotted curve to the unirradiated one. Vertical bars indicate the experimental uncertainties estimated by the scatter of data points in different runs of measurements.

The small-angle scattering from the irradiated sample is seen to have a hump centred at $s = 0.05$ Å$^{-1}$. This reminds us of the small-angle scattering of the age-hardened Al- Ag alloy as observed by Walker & Guinier (1953), where a hump was observed in the intensity distribution and was interpreted as due to the precipitation of spherical clusters. The central portions of the cluster, rich in Ag, are surrounded by peripheral regions rich in Al; this structure brings about inhomogeneities in the electron density.

The arrangement of Pd atoms in a-Pd$_{80}$Si$_{20}$ within the range of several Å seem to be insensitive to the irradiation (Fig. 1) as far as the scattering data up to $s = 1.2$ Å$^{-1}$ are concerned. The irradiation gives rise to structural inhomogeneities of longer range (Fig. 2). These structural inhomogeneities are in fact clusters with higher electronic concentration surrounded by boundaries with lower electronic concentration, or vice versa. The diameter of the cluster including the boundary is estimated as 10–20 Å. (See also Doi, 1976.)

References


Fig. 1. Intensity distribution of wide-angle X-ray scattering before (dotted curve) and after (continuous curve) the irradiation. Bars indicate the experimental uncertainties. (Doi et al. 1977).

Fig. 2. Intensity distribution of small-angle X-ray scattering before (open circles and dotted curve) and after (filled circles and continuous curve) the irradiation. Bars indicate the experimental uncertainties.