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A Comparative Study of X-ray Huang Scattering and Neutron Small-Angle Scattering from Co Precipitates in Cu

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In solid-state physics small-angle scattering near the reciprocal origin is a subcase of the more general situation of studying diffuse scattering at Bragg reflexions. In this work two difficulties connected with scattering studies on metal alloys near Bragg reflexion (Huang scattering) have been overcome. These are the smearing because of the crystal mosaic spread and an incomplete scattering theory. Cu–1 % Co single crystals with low dislocation densities and very regular cell structures have been grown by the Bridgman technique (F. W. Young, Oak Ridge) and were homogenized at 1000°C for 14 days. Rod-like cells 1 mm^2 cross section by more than 10 mm long showed in Bragg scattering the intrinsic line width of perfect copper. Thus, Huang scattering could be observed very close to the Bragg peaks both in the radial and the azimuthal directions. The scattering resulting from Co precipitates of about 150 Å diameter was a factor ten above the background defined by the scattering from quenched samples. It was studied in a large region of reciprocal space around the 400 reflexion both with a two- and a three-axis spectrometer. After correction for the well-resolved interparticle interference effect the scattering data were compared with the theoretical scattering cross sections for a single particle. The cross sections are obtained from the Fourier transform of $[\exp(i\mathbf{h}\,.\,\mathbf{s})-1]$ in which $\mathbf{s}$ and $\mathbf{h}$ are the displacement and reciprocal-lattice vectors respectively. The difficulties were (i) that $\mathbf{h}\,.\,\mathbf{s}$ is large and the usual expansion of the exponential was not possible, and (ii) the cubic anisotropy of the Cu matrix must be taken into account. For the calculation of the scattering cross sections, in addition to the known lattice-parameter change, only a single adjustable parameter is required, namely the mean radius of the spherical precipitates. With this it is possible to explain the shape, the asymmetry and the absolute intensity of the X-ray Huang scattering. In addition, the same mean radius explains satisfactorily the absolute scattering curve in an independent neutron small-angle scattering experiment on the same sample.

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Neutron Irradiation Damage in Boron Carbide

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Boron carbide is a potential neutron-absorber material for fast-reactor control systems. It is, therefore, essential that its response to prolonged fast-neutron irradiation be well characterized. Because of the brittle, frangible nature of B_4C, thinning for microstructural analysis by electron microscopy is a tedious, and frequently unsuccessful, procedure. Small-angle scattering techniques do not require such elaborate sample preparation and have been employed in post-irradiation characterization of irradiated B_4C. Samples irradiated at 760°C to 8×10^{20} captures/cm^3 showed very strong scattering, characteristic of double-Bragg effects. The high-angle diffraction lines were much broadened also. These observations indicated that short-range strain fields were created by the defect configurations present in the sample. The double-Bragg scattering was reduced by post-irradiation annealing and was replaced by a particle-size scattering which could be analyzed by conventional techniques. The nature of the observed scattering was such that the responsible defect configurations must have a minimum electron density, namely voids, three-dimensional vacancy clusters or helium-filled bubbles. Subsequent transmission electron microscopy confirmed these conclusions.