1. Activation energy for long-range migration of self-interstitial atoms in tungsten obtained by direct measurement of radiation-induced point-defect clusters

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   The activation energy for the long-range intrinsic migration of selfinterstitial atoms (SIAs) in metals, EI m, is an important physical quantity closely associated with microstructural evolution upon energetic particle irradiation. The EI m values for various metals have been widely investigated through recovery experiments on specimens irradiated at low temperatures upon thermal annealing, and the values have been estimated from the dependence of measured quantities of the specimens on the annealing temperature. On the other hand, the dependence of measured quantities on irradiation temperature is also expected to reflect the EI m values. It is of importance to compare the EI m values obtained by these two different kinds of experiments. However, no systematic studies have been carried out along the latter line. In this study, the number densities of SIA clusters formed in tungsten upon high-energy electron irradiation are directly measured as a function of the irradiation temperature using high-voltage electron microscopy. The analysis of the experimental data shows that the EIm value is in the range from 0.088 to 0.102 eV or it is less than 0.046 eV. These values are consistent with those obtained in a recovery experiment and a theoretical study, respectively.

2. Formation and reduction of streak artefacts in electron tomography

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   We have analysed the formation of streak artefacts in the reconstruction based on the filtered back projection algorithm in electron tomography (ET) and accordingly applied an adaptive interpolation technique to artefact reduction. In the adaptive interpolation to recover the missing information, the edge positions in a projection curve were tracked to reduce the interpolation error. A simulation was used to demonstrate the effectiveness of the artefact reduction. Furthermore, image reconstruction of integrated circuit specimens in the ET experiments with the ultra-high voltage electronmicroscope show that the strong streak artefacts can be reduced effectively by our artefact reduction technique.

3. Temperature dependence of MeV-electron-irradiation-induced nanocrystallization in Zr-Pt metallic glass

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   Intermetallics, 18 (2010) 767–772

   MeV electron irradiation introduces density fluctuations in metallic glass, which lead to nanocrystallization at temperatures of 298 K and below in $Zr_{80}Pt_{20}$ metallic glass. This density fluctuation corresponds to the formation of a Frenkel pair, i.e., a vacancy–interstitial pair in the metallic crystal. Phase selection in MeV-electron-irradiation-induced crystallization exhibits temperature dependence. Two f.c.c. crystalline phases were reduced to one f.c.c. phase when the temperature was reduced from 298 K to 20 K. The formation of the quasicrystal (QC) phase during thermal crystallization affects MeVelectron-irradiation-induced crystallization.

4. Temperature dependence in density fluctuation induced crystallization in metallic glass by MeV electron irradiation

   T. Nagase and Y. Umakoshi

   Intermetallics, 2010,18, 1803-1808

   MeV electron irradiation can introduce Frenkel pairs, i.e., a vacancy-interstitial pair, in crystals. In metallic glass, density fluctuation, namely, a pair of free volume and anti-free volume, is introduced, resulting in the devitrification of the amorphous phase in some

metallic glasses. In this study, we investigated the temperature dependence of MeV-irradiation-induced crystallization of metallic glasses. Phase selection in crystallization shows a significant temperature dependence in various metallic glasses at and under 298 K. The size of the crystalline precipitates changes with irradiation temperature in some metallic glasses.

5. Electron tomography reveals the endoplasmic reticulum as a membrane source for autophagosome formation

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The origin and source of autophagosomal membranes are long-standing questions. By electron microscopy, we show that the endoplasmic reticulum (ER) associates with early autophagic structures called isolation membranes (IM) or phagophores in mammalian culture cells. Overexpression of a mutant of Atg4B, which causes defects in autophagosome formation, caused accumulation of ER-IM complexes. Electron tomography revealed the ER-IM complex as a subdomain of the ER forming a cradle encircling the IM, and showed that both ER and isolation membranes are interconnected.

6. Determination of the linear attenuation range of electron transmission through film specimens

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We have investigated the linear attenuation range of electron transmission through film specimens and its dependence on the electron energy, the acceptance half-angle of a detector or an objective aperture, and specimen properties, in the scanning transmission electron microscope (STEM) and the conventional transmission electron microscope (TEM). Electron transmission in the bright-field mode was calculated by the Monte Carlo simulation of electron scattering, and its range of the linear attenuation in film thickness was then determined by a linear least squares fit. The corresponding linear thickness range was shown to increase with the electron energy and the acceptance half-angle, although it decreased with the increase in the atomic number of specimen materials. Under the condition of a 300 kV STEM or a 3MV ultra-high voltage electron microscope (ultra-HVEM), the linear attenuation range could extend to several microns for light specimen materials, and this was validated by experimental data in the ultra-HVEM. The presented results can be helpful for accurately measuring the specimen thickness or mass from electron transmission, and estimating the deviation of electron transmission from linearity when tilting a specimen in electron tomography.

7. Langevin model for real-time Brownian dynamics of interacting nanodefects in irradiated metals

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In situ real-time electron microscope observations of metals irradiated with ultrahigh-energy electrons or energetic ions show that the dynamics of microstructural evolution in these materials is strongly influenced by long-range elastic interactions between mobile nanoscale radiation defects. Treating long-range interactions is also necessary for modeling microstructures formed in ex situ high-dose-rate ion-beam irradiation experiments, and for interpolating the ion-beam irradiation data to the low-dose-rate limit characterizing the neutron irradiation environments of fission or fusion power plants. We show that simulations, performed using an algorithm where nanoscale radiation defects are treated as interacting Langevin particles, are able to match and explain the real-time dynamics of nanodefects observed in in situ electron microscope experiments.