CROWDION MECHANISM OF PLASTIC DEFORMATION

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It was established in [1] that at a limited mobility of the dislocations in brittle materials, the plastic deformation is controlled to a considerable degree by the displacement of the interstitial atoms in the form of dynamic crowdions. In the present paper we show that plastic deformation of tungsten at mechanical stresses close to the theoretical ultimate strength and at low temperatures may be connected with the formation and diffusion displacement of interstitial atoms with a mobility that is characteristic of metastable crowdion configurations.

Needle-like tungsten samples with purity better than 99.99% and diameter 200 - 2000 Å at the tip were loaded by ponderomotove forces of the electric field in a vacuum chamber of an ion field-emission microscope with nitrogen cooling [2]. The interstitial atoms were registered by the appearance of characteristic localized centers with increased emission contrast on the field-emission photographs [3].

The ion field-emission images of the samples, in which it was possible to produce plastic deformation at ~80°K by applying a load σ in the interval 1000-1500 kg/mm^2, revealed the emergence of an appreciable number of interstitial atoms to the surface. Figure 1 shows an ion field-emission photograph of a section of the surface of a needle-like microcrystal with diameter ~800 Å after a microdeformation jump in a field of intensity ~500 MV/cm ($\sigma \simeq 1100$ kg/mm^2). As seen from the figure, the interstitial atoms are observed not only in the maximum distortion region (A), but also at a considerable distance from it (B). The location of the interstitial atoms, as follows from an analysis of the photographs, is not connected with the emergence of the dislocations to the surface. Recognizing that the intermixed tungsten atoms remain practically immobile up to room temperatures [3], their observation at distances exceeding 500 Å from the damage zone at ~80°K gives grounds for assuming that they are displaced either in the form of dynamic crowdions [1] or by diffusion in a metastable crowdion configuration characterized, as shown earlier (see e.g., [4]) by a low migration activation energy.

The field-emission microscopy observations show that in strong electric fields, close to the evaporation field F ($\Delta F \sim 0.1F$), the interstitial atoms produced during the course of deformation are not evaporated from the surface. On the basis of the theory of ion evaporation in an electric field [5] it can be shown that the maximum kinetic energy of the atom emerging to the surface is given by

$$E = \frac{1}{2}\frac{\Delta F}{F}\left[\Lambda + I_n - n\phi + \frac{1}{2}(\alpha_0 - \alpha_i)F^2\right], \quad (1)$$

where Λ is the heat of sublimation, I_n is the potential of n-fold ionization, ϕ is the work function, α_0 is the polarizability of the atoms in the metal in the surface site of the

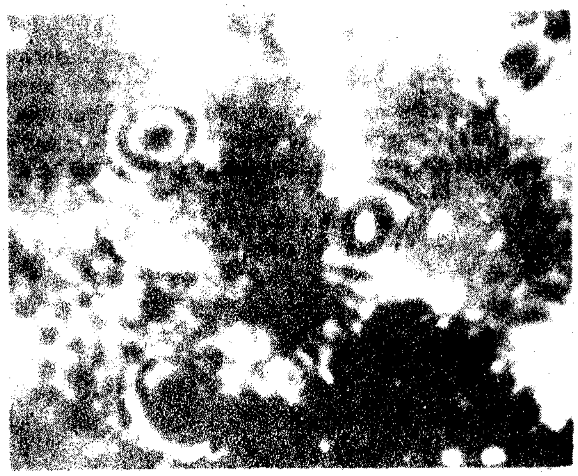

Fig. 1. Ion field-emission image of a section of the surface of a deformed microcrystal of tungsten. The arrows denote the interstitial atoms.

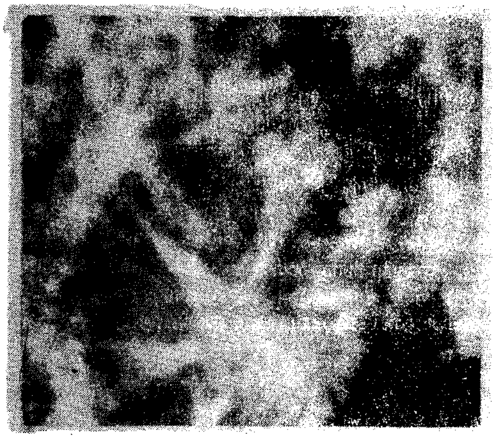

Fig. 2. Needle-like tungsten crystal after a microdeformation jump, σ = 1500 kg/mm^2, T ≈ 80°K.

lattice, and α_i is the polarizability of the free ions.

A calculation based on formula (1) shows that the energy of an interstitial atom emerging to the surface during the course of plastic deformation does not exceed 0.5 eV. This value is smaller by two orders of magnitude than the minimum energy characteristic of the propagation of dynamic crowdions [6]. At lower energies, conversion of the dynamic crowdions into focusons takes place, and the emergence of the latter to the surface would be accompanied by removal of surface atoms. Thus, the displacement of crowdions in low-temperature deformation of tungsten has a diffusion rather than dynamic character.

In many cases one observes, at loads up to 1500 kg/mm^2, a jump-like change in the shape of the sample; in this case the field-emission images do not reveal the microsteps characteristic of dislocation deformation. A crystal formed initially by evaporation in the field, loses its initial crystallographic faceting and a large number of displaced atoms are observed on the surface. The flux of atoms necessary to realize the observed deformation (Fig. 2) should be 10^{15} - 10^{16} atoms/cm^2.

It can be concluded on the basis of the presented experimental data that at low temperatures it is possible to have plastic deformation connected with migration of crowdions. This deformation can be regarded as a particular case of diffusion creep described by the Herring-Nabaro-Lifshitz model in the high-temperature region [7 - 9].

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OBSERVATION OF γ QUANTA WITH ENERGY LARGER THAN 100 MeV FROM THE RADIO SOURCE 3C120

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