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STUDY OF THE DEFORMATION OF POLYCRYSTALLINE BERYLLIUM DURING COMPRESSION

V. A. Finkel' and I. I. Papirov

Physicotechnical Institute, Academy of Sciences of the Ukrainian SSR, Khar'kov

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We earlier described the results of an x-ray investigation of the deformation of beryllium single crystals with various orientations in the process of compression [1]. These studies were performed in a special x-ray press-camera [2]. The change in character of the photographs as a function of the loads applied to the specimens made it possible to qualitatively trace the effect of elastic and plastic deformation on the structure of beryllium.

The object of the present work was to obtain quantitative information on the structure of deformed beryllium; it was decided to conduct the investigation on polycrystalline metal because Laue exposures of single crystals do not permit one to make precise measurements of the deformation of the crystal lattice. Beryllium is the only metal in which the two most important properties necessary for this sort of study are combined: "transparency" to x rays which permits one to obtain information about the deformation of the entire specimen and not only its surface layer, and the high compressive strength ($\sigma_b \sim 100$-140 kg/mm^2 at 20°C) which makes it possible to work over a wide range of loads, especially in the plastic flow region.

Specimens for the study with dimensions 2 × 3 × 5 mm were cut out of billets of cast, deformed beryllium of ~99.9% purity. The x-ray patterns were recorded in a multiframe cassette using the back-reflection method with iron radiation in a cell for deforming the specimens. The exposure geometry allowed reflections to be registered from the (201) and (112) planes and occasionally from the (103) planes. The relative precision of measurement of the interplanar spacings (Δd) amounted to 0.0002 Å. In preliminary experiments it was established that the change in interplanar spacings depends on the length of time a specimen is subjected to load. Therefore the curves of d vs. σ were determined with two loading schemes: I: loading (5-10 min), exposure (3 h), loading, exposure, etc.; II: loading (5-10 min), constant load (20 h), exposure, loading, constant load, exposure, etc.

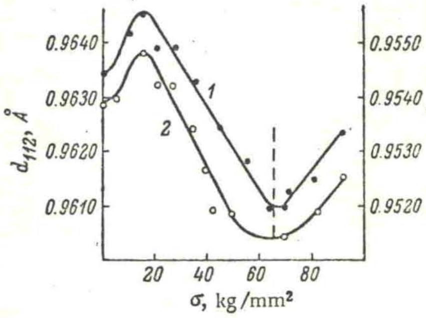

Fig. 1. The change in interplanar spacings d_{112} (1) and d_{201} (2) in polycrystalline beryllium as a function of stress under rapid loading.

The dependence of the interplanar spacing [d(σ)] on load is shown in Fig. 1 for the two pyramidal planes (201) and (112). In the reflecting position under the arrangement used for the x-ray exposures, these planes make angles of ~22.5 and ~24° respectively with the axis of loading. The variations of $d_{201}(\sigma)$ and $d_{112}(\sigma)$ have identical character; three sections are observed in the curves: σ = 0-15 kg/mm^2, where the interplanar spacings increase somewhat with increase in load; σ = 15-65 kg/mm^2, where the values of d_{201} and d_{112} decrease sharply with increase in σ; and $\sigma > 65$ kg/mm^2, where the values of d increase with the load. Apparently, in this region the true relationships are described by the dashed curve, since the transverse dimensions of the specimens are increased and in order to maintain the stress, one has to provide additional loading

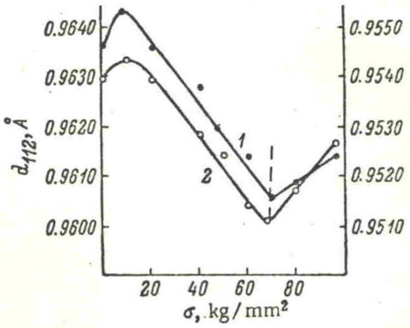

Fig. 2. The change in interplanar spacings d_{112} (1) and d_{201} (1) in polycrystalline beryllium as a function of stress under slow loading.

during the x-ray exposure. The continuous curve corresponds to calculation of d under the assumption of constancy of specimen cross section. The course of the curves $d_{201}(\sigma)$ and $d_{112}(\sigma)$ for the case of loading according to scheme II is in principle similar to that considered above (Fig. 2). It is seen, however, that the first region has contracted to 0-8 kg/mm² and in the creep region the increase in d is less than it was for the case of rapid loading.

From the data obtained, it follows that the interplanar spacings in the beryllium crystal lattice depend on the applied load in a complex, nonmonotonic manner.

For the case of elastic deformation the interplanar spacings must decrease linearly under compression. Practically, an increase in d_{201} and d_{112} occurs in the first and last stages of deformation. Changes in the crystal lattice dimensions not connected with elastic deformation can result from the following effects: 1. The specimen is in a state of quasihydrostatic compression similar to a closed high-pressure vessel; 2. Stacking faults arise during deformation which affect the values of the interplanar spacings in different ways; 3. Variation in interplanar spacings is related to the process of plastic flow, i.e., to the multiplication of dislocations, their movement and interactions.

Taking into account that plastic deformation can occur in separate grains in beryllium at relatively low stresses (the critical shear stresses for basal glide are about 1 kg/mm²), we feel that the nonmonotonic stress dependence of the interplanar spacings bears in the main a dislocation character. The effect of dislocations on volume (and, as a consequence on the interplanar spacings) has been analyzed theoretically in [3]. It is possible that the increase in d during the initial stage of deformation is related to the process of dislocation multiplication. In this case the contribution of plastic deformation to the overall deformation of the lattice must depend on the fraction of grains in which the process of plastic flow has already begun. Upon increasing the length of time during which the specimen is held under load (loading according to scheme II) the fraction of such grains is increased, which leads to the shift in the maximum on the d(σ) curves to the left (Figs. 1 and 2).

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