FORMATION OF CELLULAR STRUCTURE
IN PRESSED BERYLLIUM

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The mechanical properties of pressed beryllium were reported in [1-4].

The cellular structure of pressed metals with a fcc lattice was investigated in [5-7]. It was found that the size of the cells increases with the temperature and decreases with the rate of deformation. In this case the dislocation density in the cells decreases and the cell boundaries become narrower. The cellular and polygonized structures of rolled beryllium were investigated in [8].

This work concerns the relationship between the substructure and mechanical characteristics of pressed beryllium in relation to the deformation conditions and heat treatment.

The original materials were ingots of distilled beryllium 99.9% pure. The ingots were annealed at 1000°C for 1 h and then pressed to bars at a rate of 5 · 10⁻¹ sec⁻¹ at 400-700°C, with 55-95% deformation. The substructure was examined by means of light and electron microscopes. Electrolytic etching was used to reveal the fine structure of beryllium in a light microscope. Transmission electron microscopy was conducted on thin foils. The mechanical characteristics of pressed beryllium in bending were determined on samples 30 × 4 × 1 mm cut from bars along the axis of compression; after spark machining, the samples were ground and electropolished.

Analysis of the substructure in relation to pressing temperature showed that dislocation tangles are formed at 400 and 500°C (ε = 90%). The cellular structure is indistinct. There are sections with a polygonized structure. At a deformation temperature of 600°C the structure has well-formed cells and high dislocation density (over 10⁸ cm⁻²) within the cells (Fig. 1a). The cell size is around 1 μ. Aging occurs in the process of deformation at 600°C, with precipitation primarily in boundaries and subboundaries. Deformation at 700°C is accompanied by increasing structural heterogeneity (Fig. 1b). The dislocation density in the cells remains as high as before.

The degree of deformation affects the structure. In bars pressed at 700°C with 55% deformation the cellular structure is indistinct. With increasing deformation up to 95% the substructure becomes more perfect, the largest changes occurring at large deformations. With over 90% compression a homogeneous cellular structure is formed, as after pressing at 600°C with 80% deformation. The cell size increases somewhat (up to 3 μ).

Annealing of deformed beryllium at temperatures above 600°C is accompanied by uneven deformation. Selective cell growth at 600-700°C leads to extreme heterogeneity. Grains are formed in separate sections, with almost no change in the structure of neighboring sections (Fig. 1c). At the beginning of annealing at 700°C the cell boundaries become narrower, and the dislocation density in the cells decreases to 10⁷ to 10⁸ cm⁻². After annealing, hexagonal networks of dislocations (low-angle boundaries) are formed in some cells. Complete recrystallization occurs after annealing at 750°C for several minutes, while at 700°C it takes several hours (Fig. 1d).

To determine the effect of the structure on the plastic characteristics of beryllium we plotted the temperature dependence of the bending angle of bars pressed and annealed at 700°C. After pressing, all samples were quite brittle up to 150°C, and therefore the mechanical properties were not determined.

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Fig. 1. Microstructure of pressed beryllium (90% deformation). a) Deformation at 600°C (17,000 ×); b) at 700°C (8500 ×); c) at 700°C; d) same as (c) + annealing at 700°C for 2 h (260 ×).

Fig. 2. Temperature dependence of the bending angle of beryllium after pressing with 90% deformation and annealing at 700°C for 2 h. 1) Pressed at 600°C; 2) 400°C; 3) 700°C.

Fig. 3. Temperature dependence of bending angle for beryllium pressed and annealed at 700°C. 1) $\varepsilon = 55\%$; 2) $\varepsilon = 75\%$; 3) $\varepsilon = 90\%$; 4) $\varepsilon = 95\%$.

Figure 2 shows the variation of the bending angle with testing temperature. The temperature corresponding to a bending angle of 90° is lowest (about 50°C) for rods pressed at 600°C. After compression at 400 and 700°C it is twice as high.

The change in the bending angle in relation to testing temperature for bars with different degrees of deformation at 700°C is shown in Fig. 3. With increasing deformation the bending angle first decreases, then increases sharply at 95% deformation. The proof stress increases continuously in this case.

Analysis of the data obtained indicates that 55-95% deformation at 400-700°C does not produce a perfect substructure of beryllium with a low density of dislocation forests. In all cases the metal is quite brittle. The high brittleness of deformed beryllium is evidently due to the high dislocation density in cells (over $10^8$ cm$^{-2}$). The optimal deformation temperature, corresponding to the most homogeneous substructure