BISMUTH CRYSTAL TWINNING IN THERMAL CYCLING

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It was found that thermal cycling of monocrystalline bismuth in a regime of (77 $\rightleftharpoons$ 373°K) leads to the appearance of a network of system $\{110\}$ thermal twins in the surface layer of the specimens, accompanied by a decrease in microhardness at low loading.

In the majority of studies on the principles of plastic deformation, mechanical twinning is considered to be an unfavorable phenomenon, to which brittle fracture of crystalline bodies is related [1–3]. However, data exist [4–6] which permit the assumption that the plasticity of materials can be increased significantly by using deformation by twinning. In the present study it will be shown that thermal cycling of monocrystalline bismuth can produce a reduction in hardness in the zone in which a network of thermal twins is formed.

The objects studied were monocrystalline specimens of bismuth which were deformed essentially by twinning. The surface layers of the specimens were subjected to repeated thermal stress produced by cycling over the temperature range (77–373)°K. The mean rate of temperature change was 20 deg/sec with maximum rate of 50 deg/sec. One heating-cooling cycle required 40 sec. Cycling was interrupted for metallurgical testing of the structure and measurement of microhardness in the (111) plane. No phase transitions were observed in the bismuth over this temperature range.

After 20–30 cycles the first signs of plastic deformation due to twinning became visible. In isolated regions of the (111) plane groups of small twins appeared, sometimes forming characteristic patterns (Fig. 1a). With subsequent cycling the previously formed twins grew in size and new ones appeared. After 150–200 cycles the entire (111) surface was coated by a uniform network of fine systems $\{110\}$ twins (Fig. 1b). The thickness of the individual twins was 2–5 μm with lengths of 30–40 μm. The total area occupied by the twins comprised 15–20% of the (111) plane. Twins belonging to different crystallographic planes intersected with no secondary twinning or fracture.

Study of the structure of the cleavage plane within the volume of the crystal revealed that in thermal cycling twins develop only in a surface layer, the thickness of which does not exceed the linear dimensions of the individual twins. This is also indicated by the change in microhardness of the surface layer during thermal cycling. For small loads of 5–10 gf, where the indentor penetration does not exceed 10–15 μm, the microhardness decreases upon appearance of the twins by a factor of almost two. The microhardness at an indentor loading of 30–40 gf remains practically unchanged. The reduction in surface layer microhardness at small loads can be explained by slip in the twins produced during thermal cycling.

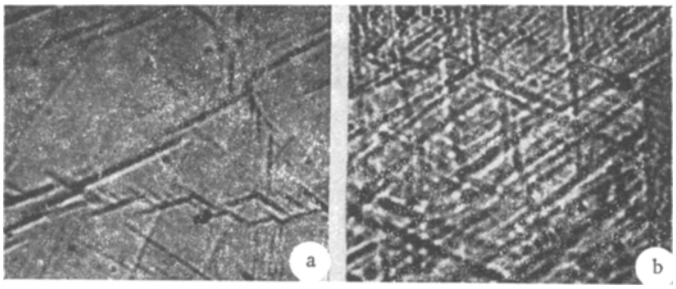

Fig. 1. Twins on (111) plane after 30 cycles (a) and crystal structure after 200 cycles (b); ×400.

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