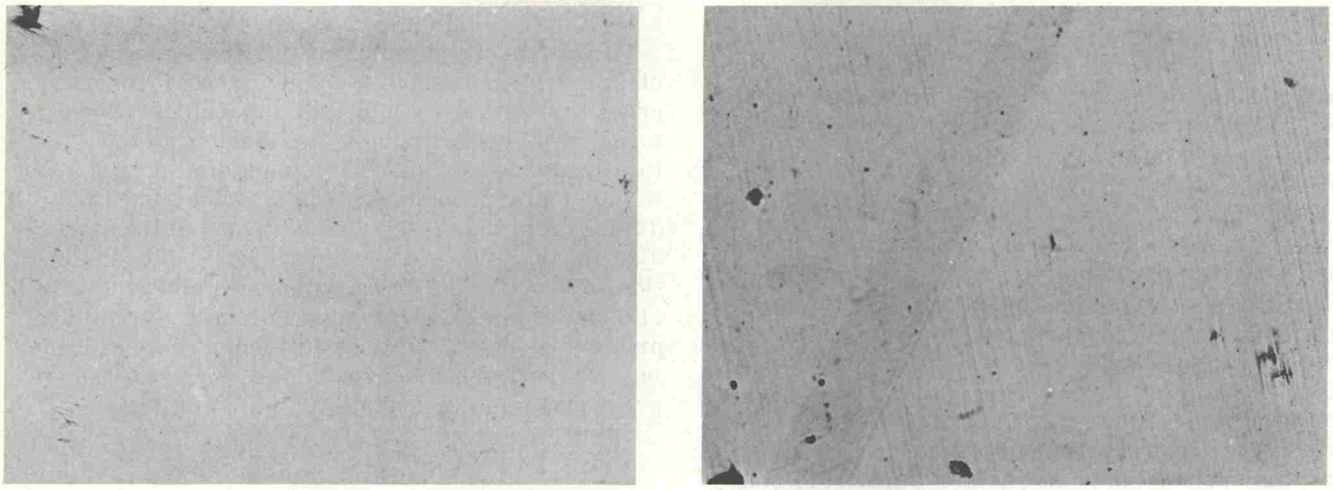
(a) 5000 atm (b) 10,000 atm

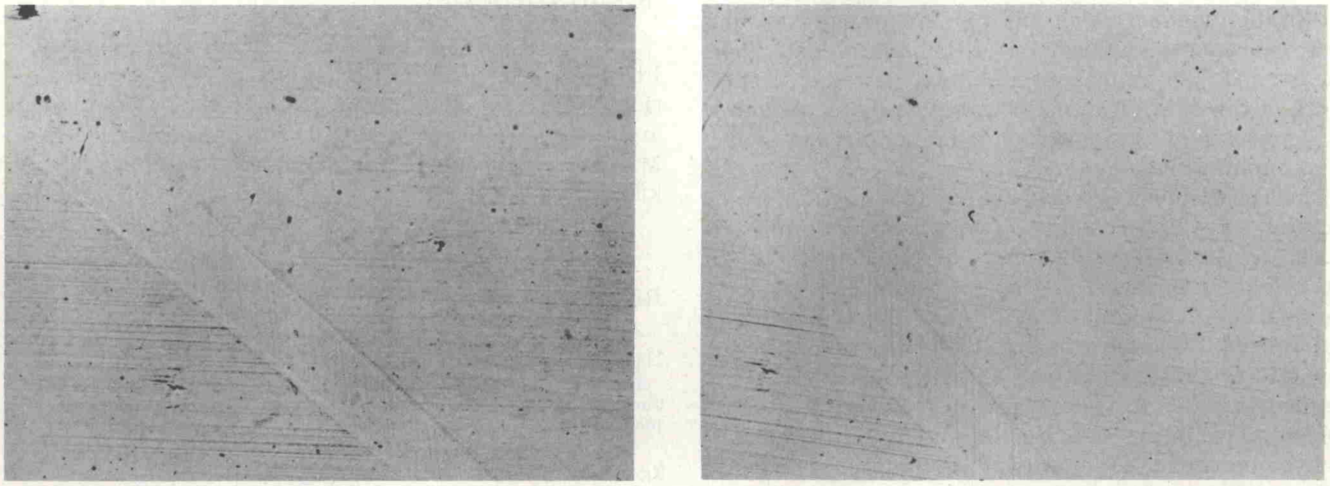
(c) 15,000 atm (d) 20,000 atm

Fig. 12—Mechanically twinned area subsequently subjected to extreme pressure. X100. Enlarged approximately 5 pct for reproduction.

slip has occurred, are almost continuous across the original grain boundary to the point where the concentrated deformation has progressively occurred. It appears, then, that in some manner the material in the region between the original boundary and the area of concentrated deformation has rotated to an orientation closely approximating that of the adjacent grain. A plausible explanation is that what appears to be the concentrated deformation is actually a form of grain boundary migration. Since the testing temperature of approximately 293 °K is somewhat greater than 1/2 of the absolute melting temperature of 544 °K for bismuth, the test conditions are within the range where boundary migration might be expected.

Other less plausible mechanisms are that the lattice adjacent to the boundary has undergone severe and concentrated bending or even fragmentation by cleavage along the (111) plane. Studies now underway to determine the effects of time and temperature on the type and magnitude of the observed phenomenon should lead to a better understanding of the mechanism involved.

The second general type of deformation observed is that of generalized slip and, in the later stages, multiple glide as shown in Figs. 5 and 6. This type of deformation is quite general throughout most of the prepared surface, becoming more generalized and increasing in intensity as the pressure is increased.

It is also interesting to note that there are substantial differences between the general deformation picture induced by extreme pressure as compared to that associated with uniaxial compression as shown in Figs. 8 and 9 for a series of strains ranging from 0 to 5 pct. As can be seen, initial deformation is predominantly by slip and at somewhat higher strains by a combination of slip and twinning which has been previously discussed by Gyndyn and Startsev.[5] Although there is some deformation concentrated near the boundaries, it is apparently, a bending type phenomenon, and, as evidenced from the comparison of Fig. 9 with 2 through 4, not the same as that induced by hydrostatic compression. A further comparison is shown in Fig. 10 which consists of a specimen uniaxially strained as shown in Fig. 9, then exposed to pressures of 20,000 atm. The boundary type phenomenon characteristic of extreme pressure can be readily seen superimposed on the results of uniaxial straining. The specimen, shown in Fig. 11, was first deformed by an extreme pressure of 20,000 atm, then uniaxially compressed 3 pct. The difference between the two types of deformation caused by the different stress states is again obvious.

It is interesting to note that although twinning is a primary mode of deformation in uniaxial compression, none has been detected in the many specimens deformed by extreme pressure. Fig. 12 shows a twin, mechanically induced prior to subjecting the specimen to pressure. As can be seen, there is a narrow band along each side of the original twin boundary that tends to increase in width as the pressure is increased. It is interesting to note, however, that this narrow band exhibits slip parallel to both the matrix surrounding the twin and the material within the twinned region. It appears, then, that this band represents somewhat of a transition zone, and may or may not represent an actual increase in the width of the twin. A more detailed study of the effects of extreme pressure on twinning and the twin mechanism is now underway.

The results presented herein cover only the effects of extreme pressure on polycrystalline bismuth. Work is either underway or planned for near future execution into the study of the effects of extreme pressure on materials of varied structures and degrees of anisotropy. In these studies, bicrystals of varied relative orientation will be examined in order to understand more fully the conrolling parameters including symmetry, orientation, and temperature, associated with anisotropy induced deformation, and to gain quantitative data which may be compared to theory. It is felt that a knowledge of how a hydrostatic stress state effects the basic structure of materials is necessary in order to study and explain accurately many of the extreme pressure phenomena exhibited by materials in the polycrystalline form.

CONCLUSIONS

Polycrystalline bismuth exhibits substantial plastic deformation when subjected to hydrostatic pressures as low as 5000 atm and ambient temperatures. This deformation is attributable to the localized shear stresses arising from the anisotropy in the elastic properties. The deformation, which differs from that associated with uniaxial compression, is characterized by severe localized distortion adjacent to the grain boundaries and generalized slip and cross-slip. Twinning, which is one of the primary modes of deformation under uniaxial loading, has not been observed in specimens exposed to pressures up to 20,000 atm.

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