11.3–1 HIGH PRESSURE INDUCED PLASTIC DEFORMATION IN SILICON SINGLE CRYSTALS. By J. Jung, High Pressure Research Centre, Polish Academy of Sciences, 01-142 Warsaw, Sokolowska 29/37, Poland.

Macroscopic plastic deformation of silicon single crystals (containing SiO_2 and Cu_3Si spherical inclusions), caused by annealing at hydrostatic pressure and high temperature, was studied by X-ray topography-XTT (Fig.1, $MoK_{\alpha 1}$, $\vec{g}$=(1$\bar{1}$1)) and transmission electron microscopy-TEM (Fig.2). Deformation of silicon samples observed by XTT was induced by pressures and temperatures plotted in Fig.3 (points ● and Δ, C1 and C2 samples differ in size of SiO_2 inclusions and concentration of Cu impurities, which are larger for C1 crystals). Elastic and thermal properties of self-strained material around surface scratches and cracks from which macroscopic deformation is propagated, were analysed. The elastic misfit between damaged layer at cracks and scratches and defect-free silicon matrix (Fig.4) was calculated. On the basis of theoretical and experimental data it is concluded that the plastic deformation of silicon at high pressure consists of two processes. The first is the coherency loss of cracks and scratches by the emission of dislocations at misfitting second phase precipitates (at pressures and temperatures above dashed lines in Fig.3. It is obvious that dislocations accompanying Cu_3Si particles are mainly responsible for the coherency loss as was confirmed by TEM). The second is the macroscopic yielding from incoherent cracks and scratches at lower elastic strain energies (full line in Fig.3. ξ is the strain energy density). The presented mechanism explains also the deformation behaviour of silicon crystals subjected to tensile stress at high temperatures; the generation and propagation of dislocations at oxide precipitates before the macroscopic yielding (Y. Nishino and T. Imura, Phys. Stat. Sol. (a), (1982) 73, 173).

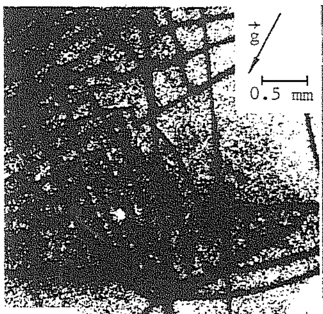


Fig.1

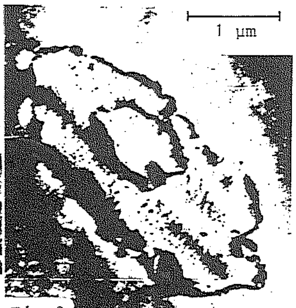


Fig.2

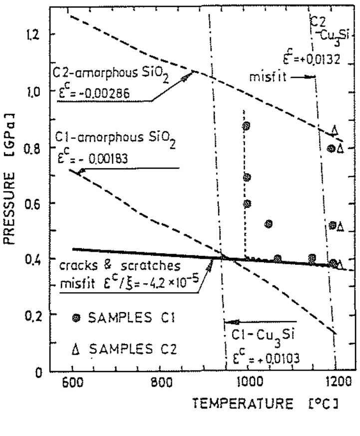


Fig.3

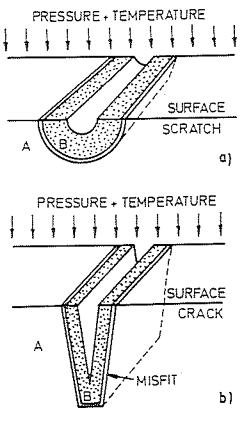
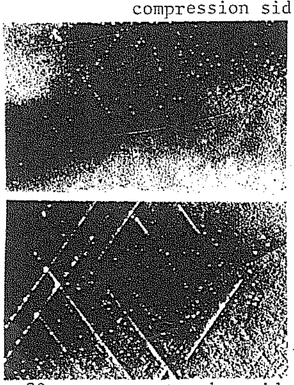


Fig.4

11.3–2 DEFORMATION TWINNING OF SILICON SINGLE CRYSTALS BELOW 600°C. By K. Yasutake, M. Umeno and H. Kawabe, Faculty of Engineering, Osaka University, Suita, Osaka, Japan.

The deformation mechanisms of silicon single crystals below 600°C have rarely been studied by macroscopic deformation tests because of their brittle nature in this temperature range. Recently Castaing et al. (Phil. Mag. (1981) A44, 1407) performed compression tests between 300°C and 600°C under the hydrostatic pressure of 1500 MPa and showed that the movements of individual partial dislocations were significant below 500°C and for higher resolved shear stresses than 200 MPa. In the present work we carried out four-point bending tests of Si crystals and found that the deformation twinning was one of dominant deformation modes of Si crystals in the lower temperature range than 600°C. Specimens (0.46 × 4.7 × 32 mm^3) prepared from (001) oriented commercial 4" dislocation-free CZ and FZ Si wafers with the bending axis [100] or [110] were deformed with the shear strain rates of 6.6 × 10^{-7} ~ 3.2 × 10^{-5} s^{-1} at 300-600°C. In the specimens bent around [100] axis at 450-600°C, twins were often observed together with slip dislocations at the compression side, while at the tension side only the slip dislocations of a/2<110> were existing. In the [110] bending, however, the deformation twins were observed only at the tension side (Fig.1). TEM and etch pit observations revealed that the deformation twins were of a/6<11$\bar{2}$>{111} type (Fig.2) and dense bundles of twinning dislocations were found on relatively thick twins by HVEM. The characteristic appearance of deformation twins is explained by considering the unidirectionarity of the twinning. In the case of [100] bending, the length along [010] direction contracts when the twin systems having the largest Schmid factor (0.47) for [010] stress are activated. Therefore, the twin systems operate only at the compression side. The [110] bending can be explained in the same manner. The deformation twins are preferably formed when the crystals are hard to deform simply by the slip mechanism. The conditions of twin formation are insufficient deformation temperature, high strain rate and low density of dislocation nucleation centers. In the [100] bent specimen stressed with 690 MPa at 450°C, many deformation twins with a small amount of slip dislocations were observed at the compression side but only a few slip dislocations were present on the other side. This might indicate that the shear resistance for the twinning dislocations is smaller than for the slip dislocations in these temperature region.

compression side



20 μm tension side

Fig.1 SEM micrographs of an etched (110) side surface of a [110] bent silicon crystal at 560°C.

1 μm

Fig.2 A TEM image of deformation twins observed at the tension side of a [110] bent silicon crystal at 560°C.