Low cycle fatigue of Si single crystals from 750 to 900°C

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Fatigue of fcc metals produces unique self-organized dislocation arrangements known as PSB (Persistent Slip Bands) associated with a single saturation stress value. Rationalized in a "composite model" the PSB collect most of the applied strain at a fixed stress and adapt to the cyclic plastic strain amplitudes only by changing their volume fraction [1].

While fcc metals have been widely investigated, almost no work exists for semiconductors [2]. The obvious reason is that semiconductors were not, until the advent of MEMS*, structural materials. However, combining the slip modes of fcc metals, a rather large dislocation dissociation width (comparable to Cu), and a large lattice friction (as in most bcc metals), silicon can be viewed as a model material for new fatigue experiments. On the darker side, its brittleness at room temperature needs to be overcome, which is the second reason why almost no one tried.

Tension/compression uniaxial testing of single crystalline Si, in single slip orientation was successfully carried out by Alain Jacques and his team between 1997 and 2002 and haven't been reproduced since then. Both the mechanical behavior and corresponding dislocation arrangements were characterized.

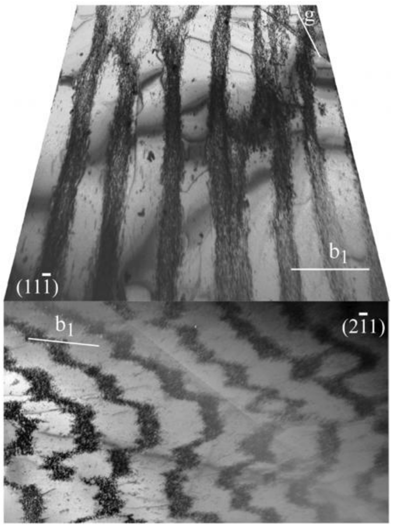

Fig.1. Dislocation wall patterning in fatigued Si single crystal

At variance from metals, two different stages of hardening occur before saturation. Both the saturation stress and the cumulative strain at saturation are lowered for larger strain amplitudes. SEM observations suggest that strain localization takes place near the maximum stress and beyond. "Ghost zones" consisting of prismatic loops created from inactive dislocation structures after saturation confirm the strain localization. Very few "ladder like" PSBs were observed and the vein structure associated with the initial hardening in fcc metals may correspond to herringbone patterns (Fig. 1). In these, dislocation walls may thin down, possibly revealing the condensation process responsible for the stress saturation

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