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LOCAL SHEAR RATE IN SLIP BANDS OF CuZn AND CuNi SINGLE CRYSTALS

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A new method, employing opto-electronic and digital storing components, has been developed to record during continuous deformation the growth of slip bands with very high resolution in time ($\approx 3 \mu\text{s}$) and in step height ($\approx 6 \text{ nm}$) by light microscopy. These records, as well as those from photometrically evaluated high-speed cinematographic films, yield the growth rate in length and in step height of slip bands. The former corresponds to the velocity of screw dislocation groups, the latter gives the local shear rate in the active slabs of the crystal. If the dislocation spacing in moving groups is known or assumed, the velocity of edge dislocations can be determined. Connection with the external deformation rate yields the active slip volume [1].

Recently it has been shown for alloys of Cu-2...10%Ni by comparison with etch-pit/stress-pulse measurements that the very first stage of development of a slip band at the front of a Lüders band corresponds to the motion of a dislocation group across the solid solution obstacles on the slip plane [2].

For thin flat Cu-30%Zn crystals (length 20 mm, width 1 mm, thickness 0.15 mm) we find on one side of the crystal (which is slightly overstressed due to the bending moment in the Lüders band front) a very rapid first stage of development (Fig.1a): within ca. $10 \mu\text{s}$ 70 - 100 dislocations appear at the surface, corresponding to a local shear rate of $\approx 10^7 \text{ s}^{-1}$. The rate then slows down by many orders of magnitude over a time of several seconds (Fig.1b), similarly as observed macroscopically in transient creep. This retardation may be connected with an evolution of local strain hardening [3] in the deformed regions of the crystal. In Cu-10%Ni a very fast period of formation does not exist for the observed slip bands, though some of them show a similar character of growth with decreasing rate, while most others grow slowly for their total life time.

For Cu-30%Zn the destruction of short range order by the first dislocations of the group and the above-mentioned bending stress at the Lüders band front appear to be reasons for the rapid first stage of development of slip bands. The dislocation velocities deduced from this period of slip band growth are about $v_s = v_e = 30 \text{ m/s}$ for Cu-5...10%Ni, and $v_s^e = 4 \text{ m/s}$, $v_e = 1.6 \text{ m/s}$ for Cu-30%Zn for screw (s) and edge (e) dislocations, respectively, at the crss (room temperature, deformation rates $\dot{\epsilon} = 8 \mu\text{m/s}$ for Cu-Ni, $\dot{\epsilon} = 1.15 \mu\text{m/s}$ for Cu-Zn alloys, respectively). Considering the slight instability at the onset of each slip band

and the effect of local work hardening during its development in the yield region, it seems that the macroscopically measured critical resolved shear stress is not simply determined by the movement of a dislocation group across the obstacle field of solute atoms in the alloy, but rather incorporates in addition the interaction between groups, and may be governed by the transfer of slip from an active slip plane to neighbouring ones. This would explain the considerable difference in the measured stress sensitivities of the dislocation velocity and of the strain rate if the latter is measured by stress relaxation experiments) [4].

References:

- [1] H.Neuhäuser, in "Dislocations in Solids" Vol.6 (Ed. F.R.N.Nabarro) North Holland Publ.Comp. Amsterdam 1983, p.319
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- [3] Y.Estrin L.P.Kubin, Acta Met. 34 (1986) 2455
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Fig. 1a) and 1b):

Increase of step height H (measured normal to the surface) of slip bands at the front of the Lüders band on a thin flat Cu-30%Zn single crystal (thickness $150 \mu\text{m}$ length 20 mm, deformation rate $\dot{\epsilon} = 1.15 \mu\text{m/s}$, $T = 300 \text{ K}$) recorded during deformation in the yield region by an opto-electronic device with different resolutions in time. The arrow indicates stop of the tensile machine.