THE IMPACT OF GRAIN BOUNDARY CHARACTER ON THE SIZE DEPENDENCE OF BI-CRYSTALS

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The deformation behavior of metallic single crystals is size dependent, as shown by several studies during the last decade [1]. Nevertheless, real structures exhibit different interfaces like grain, twin or phase boundaries. Due to the possibly higher stresses at the micron scale, the poor availability of dislocation sources and the importance of diffusion in small dimensions the mechanical behavior of samples containing interfaces can considerable differ from bulk materials. Within this study we will show the size scaling behavior of general high angle grain boundaries in copper. The first boundary presented is believed to show extensive dislocation slip transmission at bulk dimensions. The second example acts as perfect obstacle for dislocation slip transfer.

In the talk results from in situ scanning electron microscopy (SEM) and in situ µLaue diffraction will be shown. While the SEM data is used to proof slip transmission, µLaue is probing the occurrence of dislocation pile-ups at the grain boundary. The results show that at low plastic strains the size scaling behavior of single and bi-crystalline samples is identical in cases where the grain size is assumed as the critical length scale [2]. It can therefore be concluded that the initial number and size of dislocation sources is dominating not only the deformation behavior of single crystalline pillars, but also for bi-crystals (at low plastic strains) (see Fig. 1a). Thus, the character of the boundary does not play any role for the mechanical properties at the onset of yield!

This behavior is vastly different at high strains: In case of boundaries acting as obstacle the pile-up stresses at the boundary start dominating the mechanical response. In the talk, these findings will be discussed with respect to various grain boundary containing pillars published in literature.

1. Kraft, O., et al., Plasticity in confined dimensions. Annual Review of Materials Research, 2010. 40: p. 293-317.
2. Malyar, N.V., et al., Size effect in bi-crystalline micropillars with a penetrable high angle grain boundary. Acta Materialia, 2017. 129: p. 312-320.

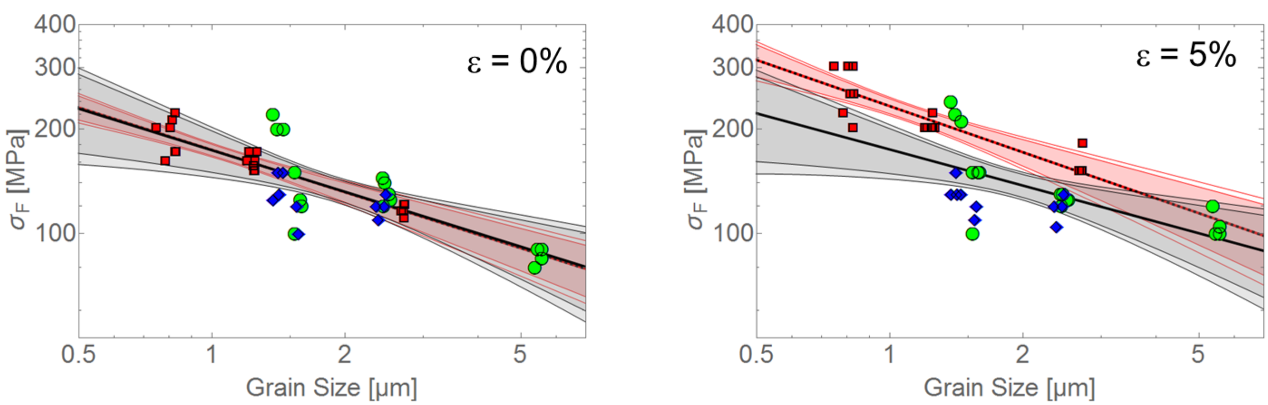

Fig. 1 Size scaling of a high angle grain boundary for flow stresses extracted (a) at the onset of yield and (b) after 5% plastic strain. Note that the bi-crystal (red) shows identical scaling as the single crystals (blue, green) at low plastic strains (a), however, as soon as dislocation pile-ups form the bi-crystal is scaling differently (b) with higher flow stresses