Grain boundary interface model in strain gradient crystal plasticity

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Introduction

Grain boundaries (GB) play an important role in metallic materials in defining their strength, reliability and life time properties, e.g. in MEMS (Fig. 1).

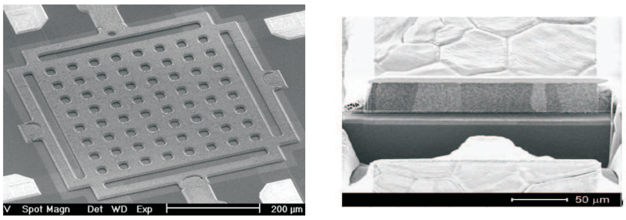

Figure 1: A metallic MEMS (left) and its grain structure (right).

At present, GB modelling lacks the critical interaction between plasticity and interfaces, which takes place at the level of individual dislocations. A better insight and quantification of the mechanisms at interfaces can only be gained through detailed analysis of these processes across different length scales: from the molecular dynamics (MD) level (TUD) via the discrete dislocations dynamics (DDD) level (RuG) to the continuum interface level (TU/e) (Fig. 2).

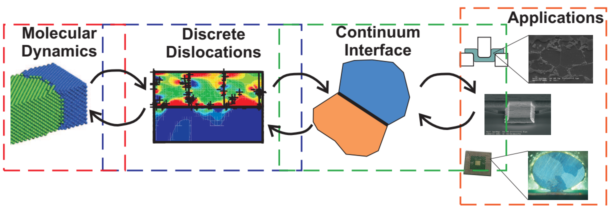

Figure 2: Scales and scale transitions up to the application level.

Experimental observations, e.g. [1], indicate that dislocations can be accumulated, transmitted, absorbed or nucleated at interfaces (Fig. 3).

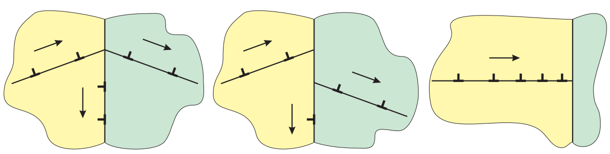

Figure 3: Interaction of dislocations with grain boundaries.

Conventional modelling approach

At the polycrystalline continuum scale, conventional modelling of interfaces in gradient enhanced crystal plasticity frameworks, e.g. [2,3], only allows to incorporate the limiting situations of either impenetrable (no slip) or infinite sink (free) GBs (Fig. 4).

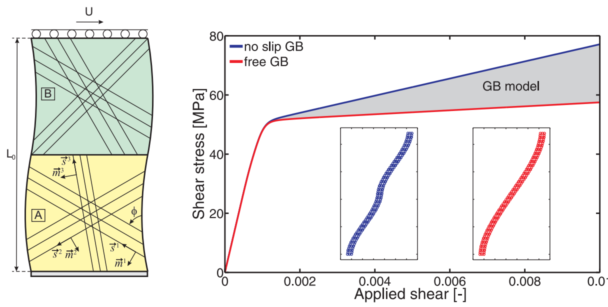

Figure 4: Bicrystal in shear (left) and GB interface conditions (right).

Enhanced interface model

The future goals are (1) to develop a GB model by means of thermodynamically consistent constitutive equations for plasticity through interfaces (Fig. 5) and (2) to use a multi-scale approach to define constitutive rules emanating from the interactions of discrete dislocations from MD and DDD analyses.

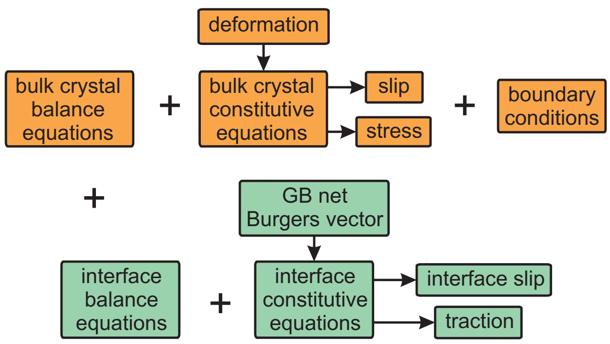

Figure 5: Schematic of enhanced framework under development.

References

[1] T.C. Lee et al., 1990, *Metall. Trans.* **21A**, 2437.
[2] L.P. Evers et al., 2004, *J. Mech. Phys. Solids* **52**, 2397.
[3] C.J. Bayley et al., 2006, *Int. J. Solids. Struct.* **43**, 7268.