Crack Interaction With Grain Boundaries in Zinc Bicrystals

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Grain boundaries are inherent defects in most materials of technological relevance. Understanding how a growing crack interacts with them will enable design of microstructures to enhance the material toughness, a desirable feature for many structural applications.

With respect to crack interaction with grain boundaries, we categorize the latter through a misorientation of the preferred fracture path across the boundary and hence we define a kink misorietation and a twist misorientation (see Figure 1). It is noted that crack path in a kink-misoriented specimen is coplanar across the boundary but not in the twist-misoriented case.

In this project, a systematic study is being performed on Zn bicrystals with predetermined grain boundary twist misorientations to document the effect the misorientation has on crack growth resistance and to understand the underlying energy absorption mechanisms using in-situ fracture experiments and three-dimensional finite element analysis (FEA).

A sequence of still images (Figure 2) extracted from a real-time movie documented during the in-situ test shows the progress of crack interaction with a 20 degree twist-misoriented boundary. The progression demonstrates crack blunting, plastic deformation by slip and twinning in both grains, grain boundary roughening, kink band formation, and multiple cracking as various mechanisms that absorb energy and discourage crack transition across the boundary. FEA helps ascertain crack-tip fields and its angular disposition in a quantitative manner and provides a basis for rationalizing experimental observations (Figure 3).

The potential in the near future to measure crack-tip fields experimentally with the desired resolution using modern techniques such as in-situ synchrotron X-ray microdiffraction will help validate the FEA results.

The understanding gained from such a fundamental study of crack-tip mechanics will enable a science-based design of microstructure for toughness-critical applications.

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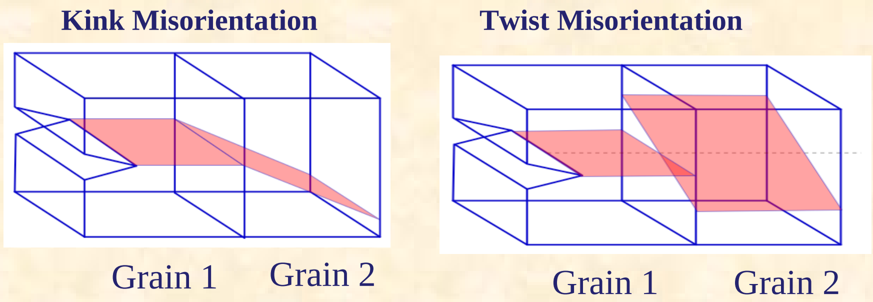

Figure 1

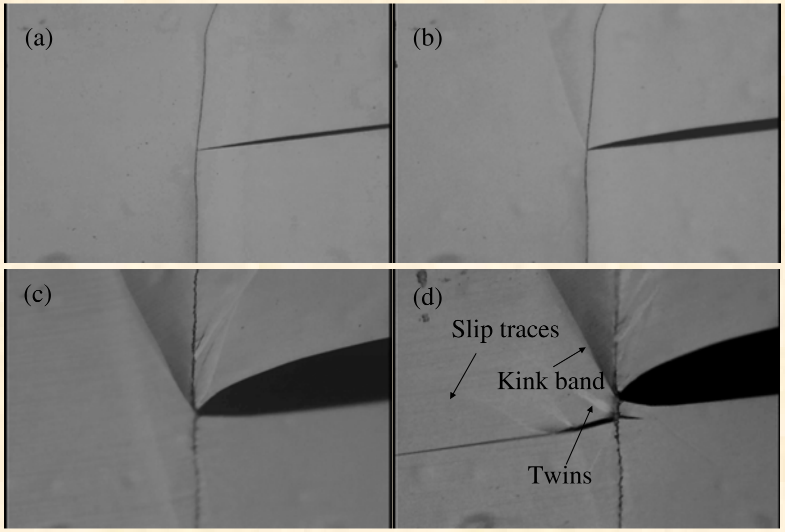

Figure 2

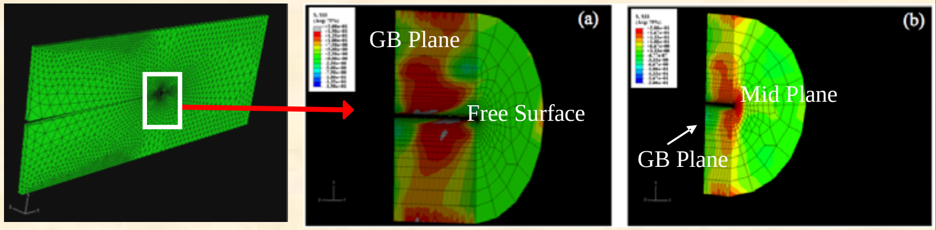

Figure 3