Crack Interaction With Microstructure: An in-situ TEM Study

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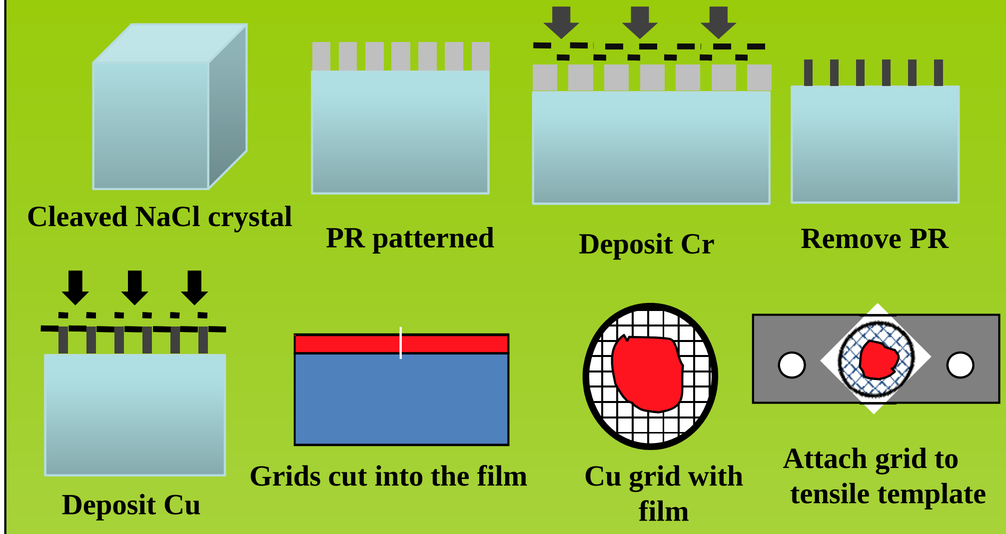
(Effort supported through the NSF-Sponsored Materials Research Science and Engineering Center-DMR-0520651)

Understanding crack growth behavior in complex materials is critical to material design for damage tolerance. An advancing crack, by virtue of its stress field, modifies the microstructure ahead of it including include changes in dislocation density, interfaces modification, decohesion of interfaces, void nucleation, and phase transformation . Such changes in microstructure can in turn have a reciprocal effect on the advancing crack. The problem is hierarchical in length scale and must be examined at the *continuum, mesoscopic and atomic* scales.

In this work, the problem is addressed at *the mesoscopic level* by examining the interaction of the crack-tip with interfaces in Cu by in-situ deformation in the transmission electron microscope (TEM). Two problems with conventional Tem specimen preparation methods include (i) differential etching of co-existing phases that can bias crack path, and (ii) no-uniform specimen thickness coupled with limited electron-transparent area that make interpretation of results from crack growth studies in the TEM difficult.

Therefore, a novel technique has been developed to grown 100-nm thick films of Cu and Cu-Cr pillar composites of uniform thickness that are electron-transparent. The technique involves vapor depositing such films on a cleaved NaCl single crystal surface (in combination with patterning and lithography to produce the pillar composites), floating them off in water, collecting them on Cu grids (mesh), attaching the mesh to a tensile stainless steel template and straining them in the TEM (Figure 1). The deformation of the mesh can be calibrated against the applied remote displacement to obtain the local biaxial strain acting on the film. The Cr pillars spatial arrangement can be controlled (Figure 2a) so that the influence of pillar size and pillar spacing may be studied. An example of an in-situ TEM straining result of crack interaction with interphase interfaces in such Cu-Cr pillar composites is shown in Figure 2b. Here interfacial debonding ahead of the primary crack due to the crack tip field is recognized. Experiments are underway to extract interface and matrix toughness insuch composite systems.

Figure 1: Schematic of thin film in-situ TEM specimen processing route.



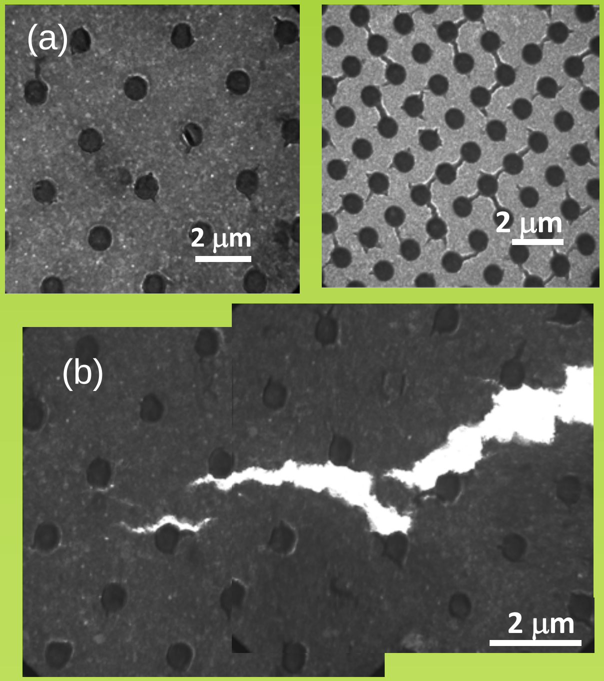


Figure 2: (a) TEM Images confirming the ability to vary Cr pillar spacing in Cu and (b) In-situ TEM straining studies showing crack interaction with Cr pillars in a Cu Matrix,