Analyses of crack growth along interface of patterned wafer-level Cu-Cu bonds

A preliminary theoretical study is carried out of the role of micron-scale patterning on the interface toughness of bonded Cu-to-Cu nanometer-scale films. The work is motivated by the experimental studies of [Tadepalli, R., Turner, K.T., Thompson, C.V., 2008b. Effects of patterning on the interface toughness of wafer-level Cu-Cu bonds. Acta Materialia 56, 438-447; Tadepalli, R., Turner, K.T., Thompson, C.V., 2008c. Mixed-mode interface toughness of wafer-level Cu-Cu bonds using asymmetric chevron test. J. Mech. Phys. Solids 56, 707-718.] wherein 400 nm Cu films were deposited in a variety of patterns on Si wafer substrates. Specimens were then produced by bringing the Cu surfaces into contact creating thermo-compression bonds. Interface toughness of these specimens was experimentally measured. The present study focuses on interface patterns comprised of bonded strips, called lines, alternating with lines of unbonded interface, all aligned parallel to the crack front. The interface toughness model employs a cohesive zone to represent separation of the interface and J(2) flow theory of plasticity to characterize the Cu films. Remote mode I loading is imposed on the elastic Si substrates. The computational model provides the resistance curve of macroscopic crack driving force versus crack advance as dependent on the work of separation and strength of the interface as well as the pattern geometry and the parameters controlling the plasticity of the Cu films. Plasticity in the Cu films makes a major contribution to the macroscopic interface toughness measured by Tadepalli, Turner and Thompson. Highlighted in this study is the difficulty of accurately representing plastic yielding in the thin films and the challenge of capturing the full range of scales in a computational model.

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