The characterization of Cu wafer bonding is critical to the successful implementation of a three-dimensional (3D) integrated circuit (IC) technology (Figure 1). Previously, we have studied the toughness of bonded Cu interconnects using a mixed-mode fracture test [1]. We have shown that high toughness Cu bonds can be created at a bonding temperature of 300°C using the EV501 bonding tool in MTL [1].

Our present work investigates Cu bond toughness under Mode I (tensile) loading. A novel test methodology has been developed to analyze the toughness of wafer/die-level thermocompression Cu bonds. The effect of lift-off patterned Cu pad size/density on the bond toughness will be studied. Additionally, Mode I bond toughness values are useful metrics for the characterization of Cu-sealed microchannels for heatsinking (Figure 1). A theoretical study of the microchannel heat removal-bond strength trade-off has been performed to obtain optimum channel dimensions.

The fundamental limit of the toughness of a Cu bond will be probed using an UHV-AFM/deposition system. Pristine Cu films will be deposited on a substrate and a cantilever tip, and the tip-substrate adhesion will be measured, under UHV conditions, thereby maintaining oxide-free Cu surfaces. Such measurements cannot be performed on a wafer-scale due to the lack of a commercial UHV-bonding tool.

We are also investigating the quality of bonded ECP damascene-patterned Cu interconnects (NTU, Singapore). The bond toughness is evaluated using a four-point bend test. The effects of Cu film texture, Cu pattern density, and the CMP (chemical mechanical polishing) process on the bond quality are being studied. Under thermo-compression, the wafers overcome the effects of polishing non-uniformity and the dishing effect, to bond with varying degrees of success. Moreover, we have designed novel test structures to assess the reliability of bonded Cu interconnect structures.

Figure 1: 3D IC technology with thermal management. Wafers are stacked using alternate face-to-face and back-to-back bonds.

REFERENCES: