Reliability Testing of Advanced Interconnect Materials

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ABSTRACT

We describe the development of electrical test methods to evaluate damage that determines reliability in advanced, small-scale conductors, including damascene copper and aligned carbon nanotube networks. Rapid thermal cycling induced during high-current AC stressing provides a means for measuring lifetimes associated with cyclic plasticity and/or diffusive damage in damascene copper. The specific type of damage that develops depends on the line geometry and the nature of the stress state induced within the lines during cycling. Voids form in both fully passivated and partially passivated lines under high levels of hydrostatic tension. Dislocation activity takes place in partially passivated lines in the presence of high shears, as shown in figure 1 (a). Effects of AC damage on subsequent electromigration tests will also be shown, including the observation that approximately 1/3 of voids created during AC stressing move under subsequent DC stressing conditions.

High-current DC stressing provides a means for evaluating the fabrication quality of aligned carbon nanotube (CNT) networks, in what we believe to be the first lifetime degradation tests of such materials. While classic electromigration is unlikely in nanocarbon, we observed through resistance changes two forms of degradation that we believe are tied to the nanotube packing and resulting conduction path density through the network, as shown by the resistance degradation plots in figures 1 (b) and 1 (c). The structure tested in figure 1 (b) shows a gradual build-up of damage, and that in figure 1 (c) shows a more discretized form of damage accumulation, which may tie to sudden changes in network morphology due to stressing. We also discuss the utility of measuring the initial rate of resistance change as an indicator of the ability of a CNT array to sustain DC stressing for an extended period.

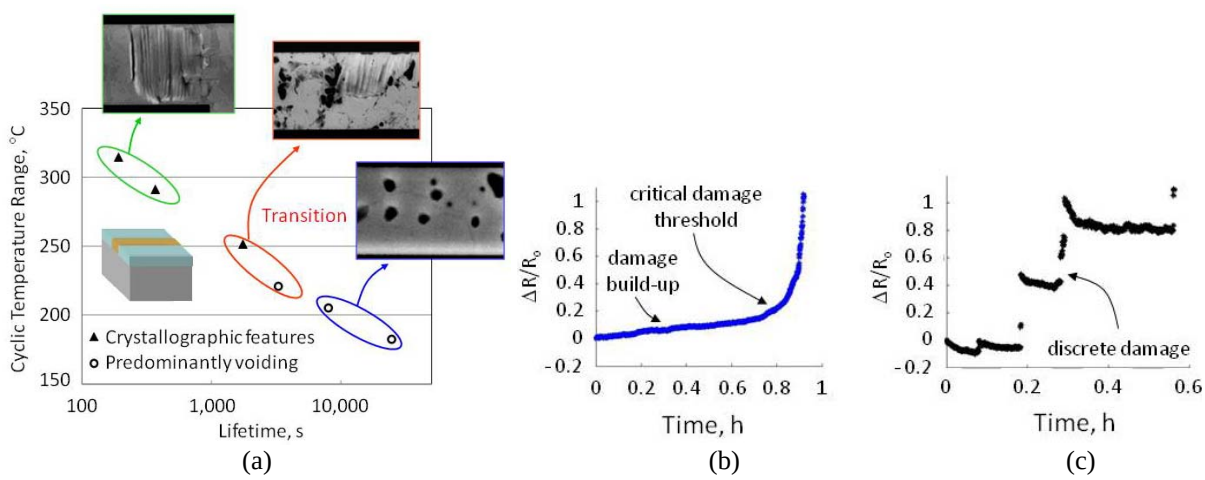

FIGURE 1. (a) Lifetime plot for damascene copper subjected to rapid thermal cycling by high-current AC stressing. (b) Resistance degradation plot for CNT networks, showing gradual buildup of damage. (c) Resistance degradation plot for CNT networks, showing discretized buildup of damage.