Effect of Aqueous Solution Chemistry on the Accelerated Cracking of Nanoporous Thin-Films

Eric P. Guyer and Reinhold H. Dauskardt
Department of Materials Science & Engineering
Stanford University
Stanford, CA 94305

Considerable effort has been directed toward integrating nanoporous inorganic ultra-low dielectric constant materials into the interconnect structures of high-density integrated circuits. The reliable fabrication of devices containing these extremely fragile materials is, however, a significant technological challenge due to their high propensity for mechanical failure during all levels of processing and subsequent device packaging in which they are subjected to mechanical loads in the presence of chemically active environments. While the effect of moisture and temperature on crack growth has recently received some attention, virtually nothing is known about the effect of more aggressive aqueous solutions. In this presentation, we demonstrate anomalously high crack growth rates of nanoporous methylsilsesquioxane (MSSQ) thin-films in weakly acidic hydrogen peroxide solutions. Results vary markedly from those predicted by solution pH, as acidic environments are generally considered to inhibit cracking. Design strategies that involve energy dissipation by local plasticity in thin ductile layers on increasing the resistance to cracking of MSSQ films are demonstrated. We elucidate the fundamental chemical interactions and molecular mechanisms responsible for the accelerated cracking in terms of the reaction rate and the mass transport of chemically active species models. Implications for the integration of nanoporous thin-films into emerging device technologies are considered.