5-2012

Load Assisted Dissolution AND Damage of Copper Surface under Single Asperity Contact: Influence of Contact Loads and Surface Environment

Pranav Shrotriya
Iowa State University, shrotriy@iastate.edu

Bun-Hiong Chua
Iowa State University

Abhijit Chandra
Iowa State University, chandra@iastate.edu

Load Assisted Dissolution AND Damage of Copper Surface under Single Asperity Contact: Influence of Contact Loads and Surface Environment

Abstract

Copper has become a widely used material in advanced submicron multilevel technologies due to its low resistivity and high electromigration resistance. Copper based devices are manufactured using additive patterning and subsequently undergo chemical mechanical planarization (CMP) to ensure good interconnection. During CMP, material is removed through synergistic combination of chemical reactions and mechanical stimulations. Empirical models such as Preston's equation are used to explain the material removal rate during CMP but a mechanism based understanding of the synergistic interactions between chemical environment and mechanical loading is still lacking.

Disciplines

Electro-Mechanical Systems

Abstract #964, 221st ECS Meeting, © 2012 The Electrochemical Society

LOAD ASSISTED DISSOLUTION AND DAMAGE OF COPPER SURFACE UNDER SINGLE ASPERITY CONTACT: INFLUENCE OF CONTACT LOADS AND SURFACE ENVIRONMENT

Pranav Shrotriya,[a] Bun-Hiong Chua,[a] and Abhijit Chandra[a]
[a] Department of Mechanical Engineering
Iowa State University, Ames, IA 50011

Copper has become a widely used material in advanced submicron multilevel technologies due to its low resistivity and high electromigration resistance. Copper based devices are manufactured using additive patterning and subsequently undergo chemical mechanical planarization (CMP) to ensure good interconnection. During CMP, material is removed through synergistic combination of chemical reactions and mechanical stimulations. Empirical models such as Preston's equation are used to explain the material removal rate during CMP but a mechanism based understanding of the synergistic interactions between chemical environment and mechanical loading is still lacking.

In this work, an experiment setup was used to investigate the effects of contact loads, surface stress state and surface environment on dissolution and damage of copper surface subjected to a single asperity loading. A range of surface stress state was generated with a four-point-bending setup on a well-polished copper sample. Single asperity contact was investigated using the cantilever tip of an Atomic Force Microscope. Controlled tip contact pressures were applied on the copper surface to mechanically stimulate the stressed surface as schematically represented in Figure 1.

The sample surface was mechanically stimulated in four different environments: ambient, de-ionized water, ammonium hydroxide and nitric acid plus BTA. Solution pH was measured before and after each experiment to monitor possible pH changes during the process. In addition, the open circuit potential (OCP) was monitored with saturated calomel reference electrode (SCE) for the aqueous environments.

Volume of material removed during the process was measured to determine material removal rate as a function of contact pressure, surface stress state and environment conditions. It shows, as expected, higher contact pressures accelerate the material removal rates. With constant pressure in slightly acidic de-ionized water, the wear rates accelerate significantly at the compressed as well as stretched surface, which gives a deep parabolic graph. In basic environment, Ammonium Hydroxide, the wear rates are almost independent of surface stress state and only affected by the contact pressure. In the acidic environment with corrosion inhibitor (BTA), increased wear rate of copper surface is measured but the surface damage rates are suppressed for both compressive and tensile surface stresses.

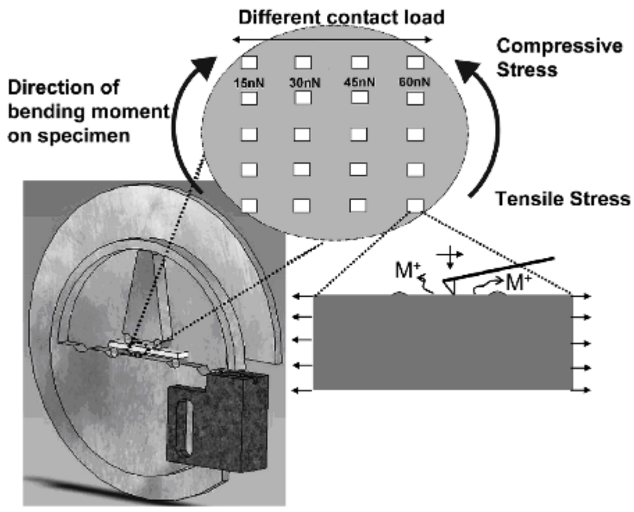

Figure 1 Schematic representation of the experiment setup consist of four elements: Base, C-clamp, capacitance gage, rollers and sample. The upper right inset shows the possible testing area and surface stress states were identified.