Direct and i*n situ* Observation of Initiation of Wear

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Wear is one of the most important failure modes in materials. The ductile versus brittle behaviour in subsurface region under sliding contact is among the least understood fundamental concepts. Conventional methodology and theory of investigation reported the possibilities of brittle fracture (surface cracks and subsurface voids) and plastic deformation. Efforts have been focused on the approach using atomic force microscopy (AFM) for nanoscale studies. Nanoabrasive wear was observed on stainless steel induced by a diamond AFM probe. Such wear is simply the downsizing of the conventional wear found at the meso- and macroscales.

Recent advancement in higher resolution characterization techniques and methodologies have make it possible to probe and study the roles of materials and fundamental mechanisms of wear in extended details. In our recent effort, we use a nanoscale approach to study wear of eutectic material systems. Simple sliding experiments were conducted using gold (Au)- and silver (Ag)-coated AFM probes to slide on a single crystal silicon (Si) wafer. The extreme dimensions of AFM probes were observed with high resolution techniques. We found that the nanowear was involved with mixed modes of abrasion and adhesion. Utilization of the eutectic system has several advantages. The Au and Ag work as a catalyst to Si to lower the system potential energy, and vice versa. We proposed that with the addition of frictional heating, it was possible to observe the morphological change due to eutectic reaction. Comparing sliding of Au and Ag would enable us to study the thermal and mechanical energy dispersion.

To understand the mechanisms and initiation of wear, we utilized an *in situ* technique by conducting nanosliding experiments under high-resolution observation. We used a gold-coated diamond indenter to slide against a single crystal silicon (110). With the movement of the indenter, cracks were initiated around the elastic contour (contact stress ring). The onsets preceded one after the other. Dislocations were found along the ring cracks only after the gold indenter was removed. The onset was initiated by voids formed during sliding. Further analysis was conducted to detect the interfacial interactions between gold and silicon. Results showed that the gold-coated probes sliding on single crystal silicon substrates promoted the inter-diffusion of Au and Si, resulting in the formation of metastable gold silicide ($AuSi_{3)}$ nanostructures. The stress-induced formation of nonequilibrium state of $AuSi_3$ does not appear in the equilibrium Au-Si system. This means that this metastable phase was formed at room temperature under a mechanical force. The approach used here is able to precisely control the highly localized deposition of nanostructures with robust adhesion due to a chemically altered interfacial layer. In addition to the benefit of formation of these interfacial features, the stress-related non-equilibrium process observed in this study sheds light on nanocontact phenomena that may be common among nanomanipulaiton techniques.

Dr. Hong Liang is Professor at Department of Mechanical Engineering as well as Materials Science and Engineering, Texas A&M University. She has been actively involved in tribological research in nanowear, chemical-mechanical polishing, advanced materials, surfaces, and interfaces. Her current research also include nanolubricants and design and fabrication of wear resistant materials. Professor Liang is a Fellow of the American Society of Mechanical Engineers (ASME) and a Fellow of the Society of Tribologists and Lubrication Engineers (STLE). She is currently an editor of the Tribology International, and a regional editor of Surface Topography: Metrology and Properties.