CHARACTERIZATION OF TRIBO-CHEMISTRY IN HARD NANOSTRUCTURED CARBON MATERIALS USING X-PEEM SPECTROMICROSCOPY


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The tribo-chemistry of sliding surfaces in contact plays an important role in determining the wear and friction properties of interfaces from macro to nano-scale applications. Ultrananocrystalline diamond (UNCD) and tetrahedral amorphous carbon (ta-C) films are particularly promising materials for a range of demanding applications to macro, micro, and nanodevices, because of their exceptional mechanical and tribological properties. However, the mechanisms controlling friction and wear of UNCD and ta-C are not well understood because of a fundamental lack of understanding of tribo-chemical processes in general. Furthermore, as-deposited ta-C films have high residual stresses, and full stress relief is possible by post-annealing at elevated temperatures (~650 °C). No systematic experimental studies have yet been reported to understand the surface chemistry and bonding configuration of ta-C after annealing, yet the annealing will likely affect its tribological properties as well.

We present studies aimed at elucidating the fundamental tribo-chemical mechanisms of wear and friction in UNCD and ta-C films. We have performed fretting and sliding wear measurements using a ball-on-disc apparatus for UNCD and ta-C films in contact with both self-mated and Si3N4 balls in ambient and controlled atmosphere conditions. The micron-scale wear tracks produced on these films have been analyzed by atomic force microscopy (AFM) and X-PEEM-NEXAFS (X-ray Photoelectron Emission Microscopy combined with Near-Edge X-ray Absorption Fine Structure) spectromicroscopy to obtain quantitative information on structural modifications and chemical changes inside the wear track. The ability of the X-PEEM spectromicroscopy technique to spatially resolve (~10 nm in ideal case) and chemically characterize regions of interest is unparalleled and therefore ideally suited for this work. The results show for the first time that it is possible to detect chemical changes with great detail occurring within the micro-scale wear track of these materials. Furthermore, we are able to establish correlations between spectroscopically-identified chemical changes within the wear track and corresponding changes in the friction coefficient recorded during tests. In the case of a UNCD film in contact with a Si3N4 ball, we see formation of SiOx complexes within the wear track, and corresponding increases in friction coefficient. In the case of a ta-C film in contact with Si3N4 ball, we observed a decrease in friction coefficient after annealing, and complex changes in the carbon bonding configuration on the surface. We will discuss the chemical changes within the wear tracks, the possible mechanisms behind them, and the resulting effect on friction and wear behavior in these films.
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