Tribological Investigation of "N3FC" Diamond-like Carbon Films Using *In Situ* TEM

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Dry lubricious coatings are a subject of increasing interest largely because of their ability to provide desirable tribological behavior that scales down easily to small device dimensions. When designing these materials, it is important to understand the complex mechanisms by which they reduce friction and wear, in order to optimize performance. However, traditional experimental techniques are unable to directly observe the sliding contact during the test, and paint a somewhat incomplete picture of the processes involved.

We study thin films of lubricious materials inside the transmission electron microscope (TEM), using a Nanofactory STM-TEM *in situ* sample holder which allows for nanoscale manipulation of the sample surface with a sharp tungsten probe tip. Repeatedly sliding the tip across the sample constitutes a nanoscale single-asperity tribology experiment where the buried interface is directly observable during the test, and we simultaneously have access to the rest of the chemical and structural analysis instrumentation in the TEM.

Diamond-like carbon films are promising lubricious coatings that can offer extremely low friction and wear characteristics under the right conditions. It is known that the chemical composition affects performance, so multiple electron energy-loss spectroscopy (EELS) studies were done to measure the carbon bonding in N3FC type films, in real time, during a sliding experiment. We will show that, after taking into account the effects of the electron beam, this technique is sensitive enough to measure, and quantify, a conversion of sp^3 to sp^2 type bonding proportional to the number of sliding passes. We further study the effects of H_2 and N_2 gas environments on these films' sliding behavior using the same technique in an environmental TEM. In addition to EELS, these studies will demonstrate structural evidence of dynamic changes during sliding using energy-filtered imaging, video, and electron diffraction. The combination of these methods provides a comprehensive look at the nanoscale single-asperity interactions that occur during a sliding contact. By filling in the data points that macroscale tests cannot access, we also come closer to a fundamental scientific understanding of the mechanisms responsible for these films' desirable friction and wear properties. This unique perspective should allow for smarter choices in both coating deposition and application.