Materials Day 2007: Sticking and Sliding, Wearing and Tearing

Tribology and Adhesion Issues in Materials Science

«Three-dimensional nanostructured films as active protection against wear»

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Tribology is defined as "the science and technology of interacting surfaces in relative motion and of the practices related thereto". The main areas of interest are friction, wear and lubrication. Both industry and academia are putting great research efforts into reducing friction and wear in moving parts in the transportation, chemical, biomedical and aerospace industries. This extends lifetime, reduces energy consumption and improves safety. A key factor in avoiding friction and wear between two sliding or rolling surfaces in relative motion under load are lubricants and especially lubricant additives. Lubricants (mostly oil) form a thin film characterized by low shear resistance that separate the moving surfaces. Under boundary lubrication conditions the film thicknesses range from 1 to 100 nm and the film is adsorbed on the substrate or the lubricant additives react with the substrate modifying its surface properties without affecting its bulk properties. Such a system constituted by two surfaces in relative motion with an interposed film can be considered analogous to a chemical reactor where the effects of temperature and pressure and of the fresh surfaces created by the friction in presence of gas, liquid or solid phases acting as lubricant are under investigation. Understanding the mechanism of proven lubricant additives as zinc dialkyldithiophosphate (ZnDTP) is essential for the development of new, metal-free lubricant additives. It requires accurate investigation of these nanometric layers and only surface-analytical methods, such as X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), time-of-flight secondary ion mass spectroscopy (ToF-SIMS) can provide these information.

In this talk, results from ball-on disk tribotests on 100Cr6 steel samples in base oil with ZnDTP at different temperatures, pressures and sliding velocities are reported. Both tribostressed areas and regions that never were in contact with a sliding counterpart were characterized by imaging XPS (i-XPS) and high-resolution XPS. The results suggest that ZnDTP interacts weakly with the steel surface at room temperature. Upon thermal treatment or by tribo-induced flash heating, the ZnDTP undergoes a thermo-oxidative decomposition: an organo-sulfur species is released into the lubricant, which may react to form zinc sulfide. Higher friction coefficients are found in correspondence with iron oxide, while lower friction is measured when the polyphosphate film is present.

This presentation highlights recent advances in understanding the chemical reactions that occur at metal surfaces while applying a pressure and under various temperature conditions.

The present results offer the promise that tribochemistry research may in the future lead, rather than follow, tribological technology.