Multifunctional surfaces and lubricants containing synthetic and renewable components

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Abstract

The creation of **novel multifunctional lubricants** and chemically modified surfaces is based on the synthesis of lubricant components and surfaces jointly conferring e.g., oxidation and corrosion protection, friction modification, as well as detergency for surface cleanliness and high degrees of dispersion of modified nano-particles. The modification of **ionic liquids** is of particular interest to achieve **long-term efficiency going along with environmental benignity** and harmlessness to human beings.

Objectives

Overall objective is the **elucidation of lubricant chemistries with high potential for use in tribosystems**, in detail:

- Multi-functional ionic liquid structures
- Understanding of nanoparticle tribology in micro- and nano-scale
- Environmentally benign compounds with lubricating moieties
- Establishing advanced analytical methods for the elucidation of degradation and lubricating mechanisms

Methodology

Molecular design of novel lubricating compounds is based on the selection of chemical structures with moieties providing both functionality and environmental benignity. Thermal-oxidative and hydrolytic stability is assessed by **artificial alteration** carried out in small-scale experiments. Analogously, **corrosiveness** is determined by immersion of metallic specimens in model fluids, e.g., ionic liquids containing corrosion inhibitors. After **tribological experiments** in boundary lubricating regime, the **tribolayer chemistry** is analysed by advanced analytical methods:

- Small-spot X-ray Photoelectron Spectroscopy (XPS)
- High accuracy and precision Mass Spectrometry (MS)
- Laser Desorption Ionisation (LDI) MS
- X-ray Absorption Near Edge Structure (XANES)

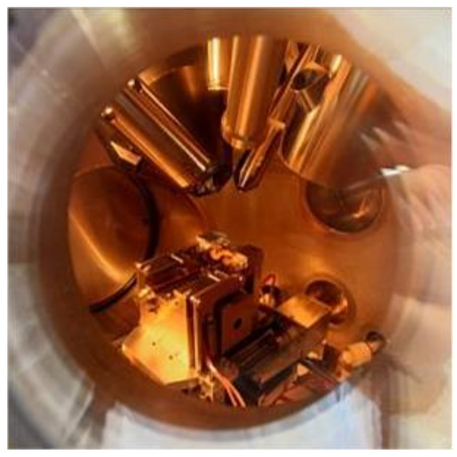

Fig. 1: Analysis chamber of small-spot XPS

Selected results

- For the first time, **joint application of MS and XPS** was performed **to elucidate the chemical composition of tribolayers**. Regarding ionic liquids, organic compounds are mainly identified by MS, and inorganic components are mainly represented by XPS findings. Moreover, **imaging techniques and depth profiling** showed that surface chemistry can be significantly localised in and outside the wear scar. The knowledge of lateral distribution of species interacting with the surface **provides better understanding of tribochemical phenomena** hence avoiding misleading conclusions that may be obtained by solely single-spot analyses.
- **Halogen-free ionic liquids** are proposed as alternatives to ionic liquids with bis(trifluoromethylsulfonyl)mide (TFSA) anion. A phosphate based ionic liquid **showed superior friction and wear behaviour under vacuum conditions** in comparison with conventional perfluorinated polyether (PFPE) and an ionic liquid with TFSA anion.
- **Ionic liquids** were fundamentally evaluated **as antiwear additives in** model oils and fully formulated **engine oils**. Research comprised screening of several ionic liquids with selected cations and anions, respectively, benchmarked against a zinc dialkyl dithiophosphate as reference. Tribochemically formed reaction layers were investigated by XPS and XANES.

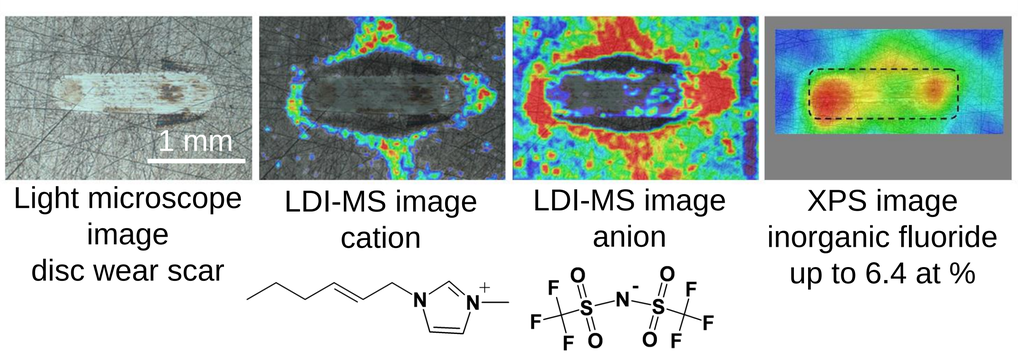

Fig. 2: Wear scars obtained from an ionic liquid after steel-on-steel sliding experiments; surface characterisation by MS imaging and XPS imaging revealed distribution of organic and inorganic species in and outside the wear scar, respectively

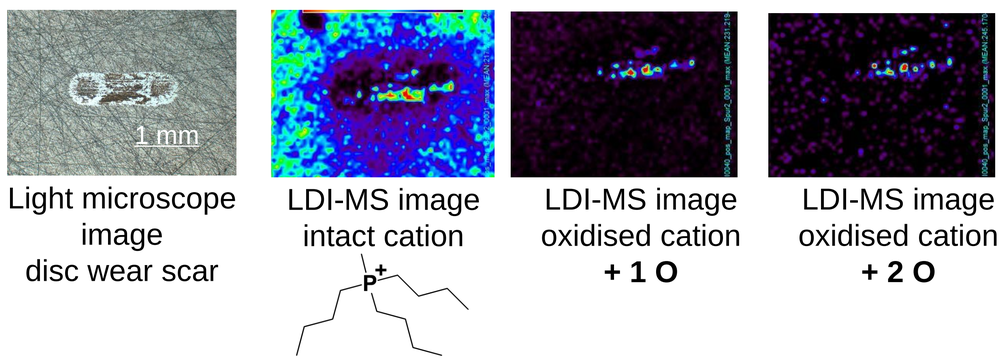

Fig. 3: MS images from a worn steel surface showing the distribution of the intact cation of an ionic liquid and two oxidation products (cation with one or two oxygen atoms) only detected in the wear scar

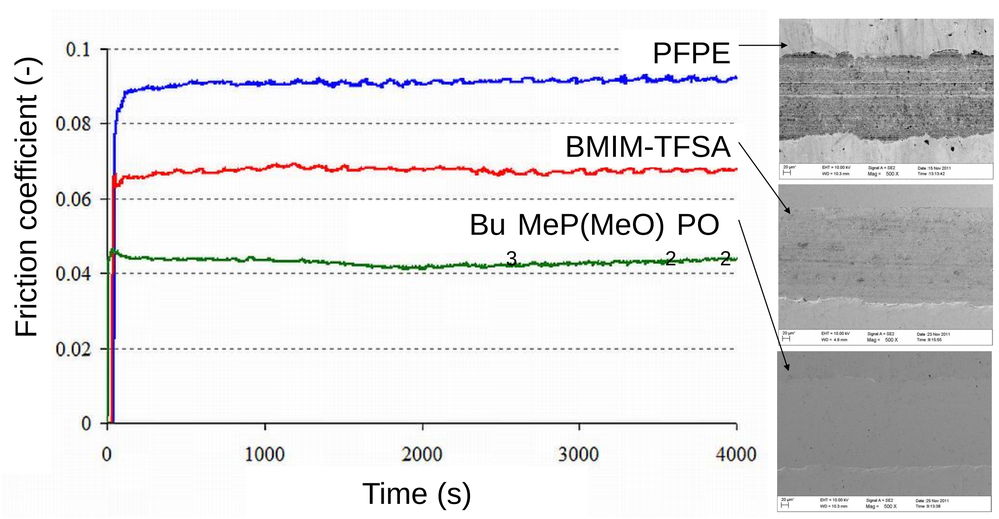

Fig. 4: Friction (left) and wear (right) obtained from steel sliding against steel lubricated with PFPE, 1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)amide (BMIM-TFSA), and tributylmethyl-phosphonium dimethylphosphate ($Bu_3MeP(MeO)_2PO_2$) in ultra-high vacuum; higher friction and pronounced wear with PFPE, best performance observed for phosphorus containing ionic liquid

Representative publications of authors

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