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Surface-analytical investigation of boundary films formed in silica contacts lubricated by *trifluoro tris(pentafluoroethyl) phosphate*-based ionic liquids

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1. Introduction

Since the first experimental investigations of ionic liquid-mediated lubrication [1], a significant number of studies have been published on the topic, mainly reporting promising tribological performance for this atypical class of lubricants. It is often suggested that reduced wear and friction are related to the formation of a boundary film within the contact area, by adsorption of ions and chemical reactions of ILs under boundary-lubrication conditions [2]. Despite reports of clear evidence of chemical changes affecting the worn areas [3], a detailed understanding of the chemical state of the elements constituting the boundary layer is generally absent, thus preventing an unambiguous correlation between observed tribological properties and the associated chemical processes.

The goal of the present work is to investigate the tribological behavior of silica contacts lubricated by *trifluoro tris(pentafluoroethyl) phosphate*-based ILs and to understand the tribochemistry that occurs when under boundary-lubrication conditions by means of surface-analytical techniques.

2. Experimental

A *UMT-2 microtribometer* working in pin-on-disc mode was used to investigate the lubricating performance of *trifluoro tris(pentafluoroethyl) phosphate*. A few droplets of lubricant were placed between the silica (Ra = 2.6 nm) pin and a silicon wafer (Ra = 0.4 nm) and tests were performed at speeds ranging from 50 to 600, mm min^{-1}, a RH of 22-32 % and at ambient temperature (22 °C). Samples were observed by optical microscopy and profilometry. In order to characterize contact and non-contact regions of the flat and of the pin, *imaging X-ray photoelectron spectroscopy (XPS)* was used, while the depth-distribution of the composition was investigated by *angle-resolved XPS*.

3. Results and discussions

The lubricating performance of the selected FAP-based ILs has been tested with an SiO_2 ball vs Si wafer. The coefficient of friction value was found to be close to 0.1 for speeds from 100 to 600 mm/min (Figure 1). At lower speeds, an increase of wear was observed, especially for the shorter-chain ILs.

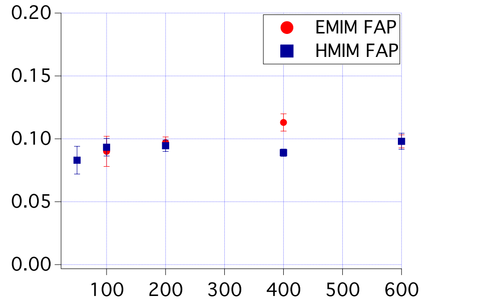

Figure 1: *Mean coefficient of friction as a function of speed for 1-ethyl-3-methyl imidazolium and 1-hexyl-3-methyl imidazolium trifluoro tris(pentafluoroethyl) phosphate (EMIM FAP and HMIM FAP, respectively); applied load: 500 mN; pin radius: 1 mm*

Following the tribological tests, the counterparts were characterized by optical microscopy, profilometry and XPS.

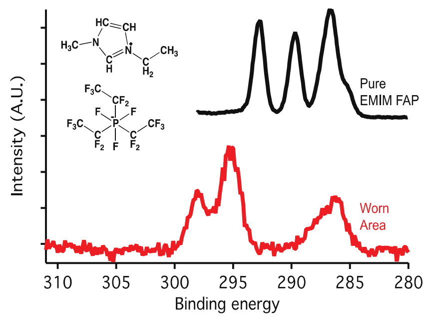

Figure 2 : *C1s region of a thick film of pure EMIM FAP (black curve) and of the worn area on silicon wafer following a tribological test (red curve)*

In particular, significant differences are revealed when comparing C1s signals of pure IL with those of the worn surfaces (Figure 2). These indicate that wear of the tribopairs is associated with a substantial change in the chemical state of adsorbed species, suggesting the reaction of anions and adsorption of fluorinated organic fragments on the Si/SiO_2 surfaces.

References

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