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Ionic liquids at interfaces, under confinement and with applied electric fields. Forces, friction, viscosity and tribotronics.

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Ionic liquids lend themselves to tribotronics – the ability to use electric fields to control friction, lubrication and wear through the use of applied potentials. We show that using tribologically relevant ionic liquids as pure lubricants and as additives in oils, it is possible to affect ordering, tribology and viscosity by the judicious application of electric fields..

Keywords: ionic liquid, AFM, surface force, nanotribology, neutron reflectance

1. Introduction

The application of electric fields has captured much interest, particularly coupled with ionic liquids and ionic liquid additives to control friction,[1] and possibly viscosity[2].The conductive nature of the interfaces required to achieve this has, however, been shown to lead to a confinement- induced crystallization of the IL in at least one case.[3] On the other hand most tribological surfaces contain a thin oxide layer, which appears to relax this constraint at least in the systems tested in our laboratories so far, and there has of course been no such observation in systems where at least one of the surfaces is non-conducting.

2. Methods

To understand the relationship between friction, forces and surface composition of these materials, Quartz crystal microbalance,Vibrational sum frequency spectroscopy and neutron reflectance have been applied at isolated interfaces, whereas confined properties have been studied using AFM and Surface Forces (ATLAS) .

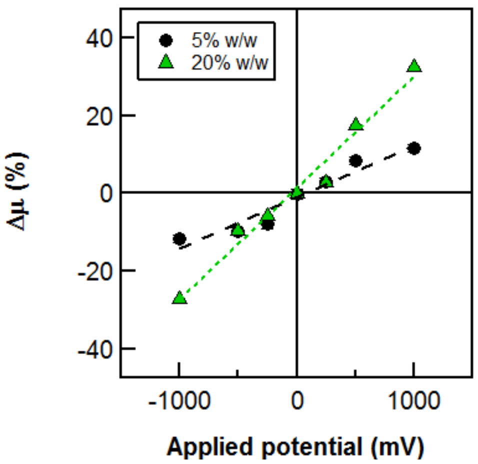

Figure 1: The response of the friction coefficient to applied electric potential depends not only on the magnitude of the potential and the resulting ion distribution on the surface, but also on the IL conc. in oil.

3. Discussion

It can clearly be seen from figure 1 that the frictional behavior depends strongly on the electric field for a tribologically relevant ionic liquid in a polar solvent. The ionic liquid is tetradecyl tri hexyl phosphonium bis mandelato borate. (PBMB) In response to the electric field the composition of the different ionic components changes and the cations would appear to be more lubricating. The picture is more complicated than this however. Neutron reflectance measurements reveal that there are significance differences in the ordering at the interface (in terms of the number of ionic layers, with associated solvent content) for the different polarities. Furthermore, water, which is a contaminant that is very hard to remove completely under ambient conditions, also has an important role. The position of accumulated water at th interface dependes very strongly on the potential, and the nature of the ions in the innermost interfacial layer. Its presence also leads to much more defined ordering in the interfacial ionic liquid layers, and also leads to a strong enhancement of the potential induced friction behaviour.

Measurements using ATLAS reveal that the viscosity is electric potential dependent to a small but measureable extent, and is able to distinguish between interfacial and confinement induced ordering. Finally QCM reveals the dynamics of the rearrangement in response to electric fields and the anisotropy thereof.

4. References

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