Tribological Properties of Poly(Ionic Liquid) Brushes in Aqueous and Organic Media– WTC 2021, Lyon

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Most surface grafted polyelectrolyte brushes are solvated in aqueous solutions and reduce interfacial friction consequently, but very few of them deliver the same level of lubrication in non-polar solvents. In the present work, Poly(Ionic Liquid) (PIL) brushes were investigated systematically in organic and aqueous solvents, and were found with an exceptional lubrication characteristics. AFM data shows that the brushes do not swell up in Dodecane but do in water, implying that the PIL brushes lubricate via two different lubrication mechanisms: the brushes would swell in water and reduce the friction, whereas the polymers collapse and minimize surface adhesive interactions to reduce friction in dodecane.

Keywords: Tribology, Polymer Brushes, Ionic Liquids, AFM.

1. Introduction

Polymers grafted onto a solid substrate have long been studied for lubrication properties. When being exposed to favourable solvents, the polymer chains 'swell' and extend out at the surface creating a solvated layer that can separate contacting surfaces. This reduces friction due to the resistance to penetration of the swollen brushes and the hydration layers surrounding the polymer brushes giving the polymer layer fluidity. The reduction in friction is dominated by swelling of the polymer brush in the lubricating solvent. This requires favourable interactions between the solvent and the polymer to enable the swelling. Hence polymer brushes tend to only reduce friction in one type of solvents and be ineffective in other solvents [1]. In the present study a series of 1-n-butyl-3-vinylimidazolium bromide ([BVIM]Br) based poly(ionic liquid) (PIL), synthesized with varying polymerization times, grafted onto a silicon surface were investigate for friction reducing capabilities in dodecane and water.

2. Methods

To investigate the friction coefficient between the PIL modified silicon surface and borosilicate glass in the two lubricating media; a linear reciprocating tribometer was used. The Atomic force microscope is used for imaging the substrates in situ to attempt to observe the brush like structure and evaluate the quality of the surfaces. The AFM was also used to measure force curves of the PIL surfaces in-situ using a borosilicate glass colloidal probe and the adhesive interaction between the borosilicate glass microsphere tip and the PIL surface was measured.

3. Results

Initial friction coefficient measurements show a reduction of friction coefficient for the PIL brushes in both water and dodecane, with dodecane showing a more marked reduction in friction relative to a silicon surface with no polymers at the surface (dashed line). To further investigate this, force curves were taken using a colloidal probe with an 8 um borosilicate microsphere tip. The data can be seen in Figure 1.

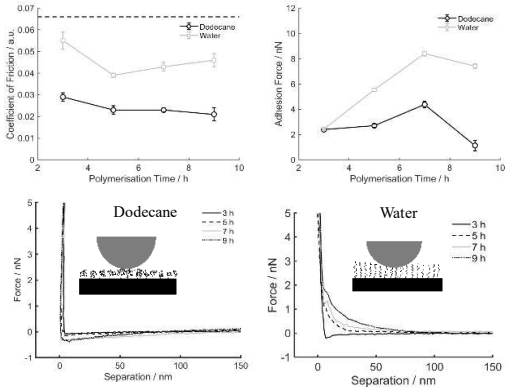

Figure 1: *(top left) – friction coefficient data relative to bare silicon surface (dotted line). (Top Right) – Adhesion force data. (Bottom) – Force curve plots in dodecane (right) and water (left).*

4. Discussion

While a reduction in friction is seen in both dodecane and water, the magnitudes of reduction differ, implying that the mechanism of lubrication might have changed. Evaluating the onset of repulsion in the force curves it is seen that in dodecane, there is little repulsion at all. This implies that in dodecane the PILs are not extending out into the brush conformation. Whereas in water, repulsion is seen and more repulsion is seen for samples that had a longer polymerization time and therefore had the longest polymer chains. This suggests that the PIL form a brush structure and reduce friction due to the osmotic pressure within the brush layer. In dodecane however, more friction reduction is seen yet the brush conformation is not taken. By looking at the adhesion forces it can be seen that in dodecane the polymer has a much weaker interfacial adhesion to the borosilicate tip than in water. Therefore it can be seen that the PIL is reducing friction in dodecane by adapting a collapsed conformation, which resulted a minimized adhesive interactions between the contacting surfaces.

5. References

[1] Zhang, Z. et al. 'Effect of Brush Thickness and Solvent Composition on the Friction Force Response of Poly(2-(methacryloyloxy)ethylphosphorylcholine)' Brushes. Langmuir 2011, 27 (6), 2514-2521.