Fundamental Aspects on Soft and Resilient Tribology of Solvent-Swollen Concentrated Polymer Brushes

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We succeeded in synthesizing a concentrated polymer brush (CPB) with extraordinarily large thickness. Most importantly, thus obtained thick CPB showed, under macro-contact condition, an excellent lubricating property, that might otherwise be spoiled by the abrasion owing to foreign particles and/or rough surface of substrates. We propose a new concept "soft & resilient tribology" to apply this CPB system on various mechanical elements for their prolonged life and energy saving.

Keywords: tribology, polymer brush, reversible-deactivation radical polymerization

1. Introduction

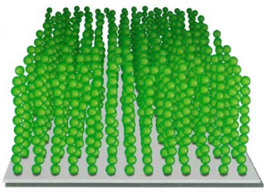

Figure 1: Schematic illustration of CPB

Polymers densely end-grafted on a solid surface are obliged to stretch away from the surface, forming a so-called "polymer brush". By successful application of living radical polymerization (also called reversible-deactivation radical polymerization) under high pressure [1] or in ionic liquids [2], we succeeded in striking increase of graft density as well as brush thickness, fabricating the "concentrated" polymer brush (CPB) of a micrometer order in thickness. This breakthrough in polymer-brush synthesis brought about dramatical improvement in tribological performance [3,4], leading to the industry-academia collaborating "ACCEL" project for practical applications. In this presentation, we will explain the outline of this project as well as the fundamental aspects of the CPBs from controlled synthesis to tribological applications.

2. Methods

Thin and thick CPBs of poly(methyl methacrylate) (PMMA) were synthesized by surface-initiated living radical polymerization under ambient and high pressures, respectively: typically, [M_n=8.9x10^4, M_w/M_n=1.19, L_d=66nm] and [M_n=2.7x10^6, M_w/M_n=1.35, L_d=1200nm], where M_n, M_n, and L_d are the number- and weight-average molecular weights and the dry thickness, respectively. The tribological properties were measured in a good solvent, *N*,*N*-diethyl-*N*-methyl-*N*-(2-methoxyethyl)ammonium bis(trifluoromethanesulfonyl)imide (DEME-TFSI), using a ball-on-disk setup on a rotatory tribometer (UMT, Bruker Co., USA) along with a glass lens of 7.79 mm in curvature radius. In some cases, in-situ optical measurement was carried out to determine the gap distance between base-substrate surfaces and hence the thickness of a swollen and lubricant layers.

3. Results and Discussion

Figure 2 shows the Stribeck plot, i.e., plot of coefficient of friction (COF) as a function of viscosity (η), velocity (v), and normal load (F_N). A thin CPB sample had little improvement in lubricating property: the COF increased at higher loads and lower speeds, similarly to the case without polymer brush. In contrast, a thick CPB achieved good lubrication: the friction in the boundary-lubrication regime was effectively reduced, realizing the hydrodynamic lubrication. The key to success was the CPB thickness. We confirmed the good correlation between the durability and the thickness by performing the wearing test for a series of samples with different thicknesses. It should be noted that this thick CPB gave sufficient durability for some practical applications. On the basis of these findings, we finally suggest a new concept "soft & resilient tribology" to characterize the CPB system.

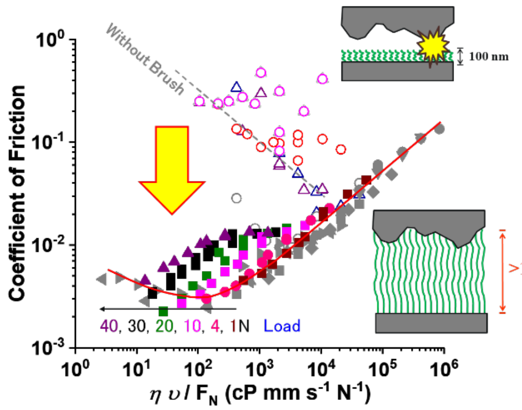

Figure 2: Stribeck curves for bare (open triangles), thin-CPB (open circles), and thick-CPB (closed symbols) samples measured in DEME-TSFI.

4. References

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