Adsorption of polar molecules on DLC coatings

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1. Introduction

Low friction, low wear and anti-adhesion properties distinguish diamond-like carbon (DLC) coatings, making them highly perspective for application in mechanical systems. DLC coatings are believed to be chemically very stable and mostly non-reactive towards the molecules in their surrounding. However, it was proven that hydrogen plays an important role in determining the tribological properties of the DLC [1]. DLC surfaces can also undergo tribochemical reactions with glycerol [2], and relatively complex additives, like ZnDDP and MoDTC [3]. On the other hand, few systematic studies on the adsorption of organic molecules with basic polar end-groups were performed on DLC [4]. However, to tailor the lubrication properties of the DLC coatings, we need to better understand the basic lubrication mechanisms, especially adsorption, which proved to be one of the fundamental boundary-lubrication mechanisms on the conventional surfaces.

2. Experimental

The adsorption properties of the DLC coatings, like a-C, a-C:H, Si-DLC and F-DLC, were investigated in this work. The molecules selected for the analyses were hexadecanol and hexadecanoic acid molecules, which were mixed into PAO base oil. Neutron reflectometry was used to study the thickness and density of adsorbed additive layers on the surfaces. TOF-SIMS and XPS analyses were used to confirm the presence of additive molecules on the surface after ultrasonic cleaning. Wettability measurements were performed to correlate the adsorption abilities with the surface energy concept.

3. Results

Neutron reflectometry study revealed full adsorbed additive layers only on a-C and a-C:H. Non-hydrogenated a-C coating proved to be the most reactive, since the adsorbed layers were formed with alcohols and fatty acids. The adsorbed layers were relatively thin (≈ 0.5 nm), but the density was almost similar to the density of the bulk additive. Somewhat less reactive was a-C:H, where adsorbed layer was detected only with the fatty acid. No complete layer was observed with the alcohol molecules. Despite that, in both cases TOF-SIMS analysis revealed the presence of additive molecules on the surface even after the ultrasonic cleaning. In contrast, neutron reflectometry revealed no full adsorption layers on F-DLC and Si-DLC. The neutron reflectometry data correlates very well with the wettability measurements.

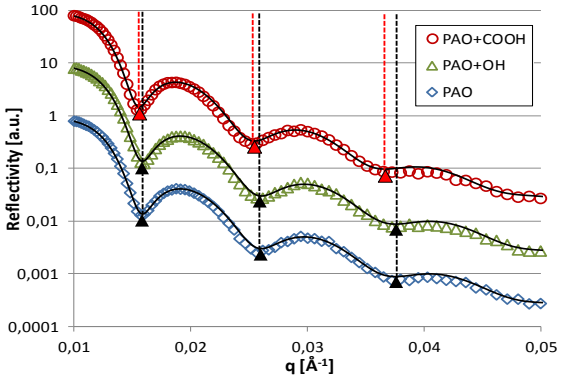

Fig.1 Neutron reflectometry profiles for a-C:H revealed adsorbed layers of hexadecanoic acid (COOH) and no adsorbed layers in case of hexadecanol (OH).

4. Conclusions

Despite the believed non-reactivity of the DLC, adsorption of polar molecules is possible. The a-C coating seems to be the most reactive, probably due to the dangling bonds, which were not passivated by the hydrogen. Namely, a-C:H has proven to be less reactive, since adsorbed layers were formed only by the fatty acid. Although no layer was formed by the alcohol, the alcohol molecules may still adsorb in smaller quantities, as revealed by TOF-SIMS and XPS. Si-DLC and F-DLC were even less reactive, which agrees well with the surface energy concept, where a-C has the highest and F-DLC the lowest surface energy.

5. References

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