The Effects of Si-Dopant on the DLC Coating Tribological Performance and Tribofilm Formation Lubricated by Organic Friction Modifier-Containing Engine Oil Formulations

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1. Introduction

Diamond-like-carbon (DLC) coatings are used in powertrain parts, such as valvetrain, fuel-injection components, piston- and cam-systems by more and more automotive manufacturers. Most of the engine oil formulations available in the market now are optimised to lubricate ferrous surfaces. Si was selected as the dopant for DLC to compare with the pure hydrogenated DLC due to its reported good tribological properties. Ikeyama et al. [1] reported that the increase of Si content in DLC resulted in the friction coefficient decreased, and there was almost no peeling off in the tribology test. This study focuses on how pure hydrogenated DLC and Si-doped DLC perform when lubricated by current engine oil formulations and then formulations with new organic friction modifiers. The tribofilm composition and tribochemistry effects are also investigated by surface analysis techniques.

2. Methodology

Hydrogenated DLC, and Si-doped DLC films were deposited on steel substrates. Coated samples were tested against steel pins using a TE-77 tribometer. Current diesel engine oil formulation was used as the test lubricant, which contains anti-wear additive zinc dialkyldithiophosphates (ZDDP). Friction was measured during the test. Wear and tribofilm composition were measured by interferometer, Time-of-Flight Secondary Ion Mass Spectrometry (TOF SIMS), and X-ray Photoelectron Spectroscopy (XPS).

3. Results and Discussion

Some of the new organic friction modifier-containing oils showed about 10% friction and 12% wear reduction compared with the current engine oil formulations. Si-DLC showed higher Ca, P, S and Zn content in the tribofilm as shown in Figure 1. Ban et al. [2] found the presence of ZnO, ZnS, $FePO_4$, FeS and FeS_2 compounds on the ZDDP formed DLC tribofilm. It was believed that these additive formed compounds contributed to achieve low friction and high wear resistance.

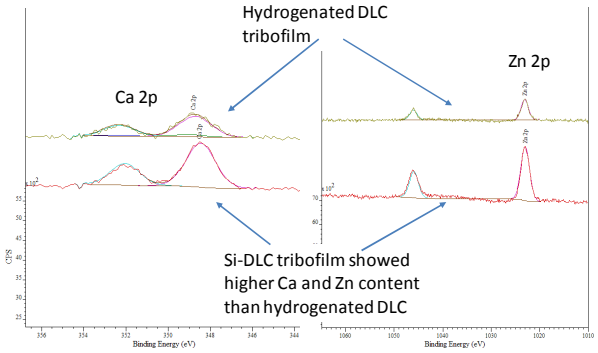

Figure 1 Ca 2p and Zn 2p peaks from the H-DLC and Si-DLC tribofilm .

4. Summary

The focus of this paper is to understand how the tribochemistry film affects performance. Post-test surface analysis, TOF SIMS showed that the organic friction modifier could improve the P- and OH- group surface adsorptions on the wear track. Si-doped DLCs had thicker tribofilms formed on the surface than pure hydrogenated DLC. XPS depth profile results showed that an oxide layer formed underneath the P- and Zn-containing “tribo-layer”.

The link between tribological performance and the influence of Si dopant on tribofilm formation is discussed in detail in the paper.

References

1. Ikeyama, M., et al., *Effects of Si content in DLC films on their friction and wear properties.* Surface and Coatings Technology, 2005. **191**(1): p. 38-42.
2. Ban, M., et al., *Tribological characteristics of Si-containing diamond-like carbon films under oil-lubrication.* Wear, 2002. **253**(3-4): p. 331-338.