How to Manage Friction and Wear of Diamond-like Carbon Coatings lubricated with ZDDP additive?

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In various industrial applications, friction and wear reduction by diamond-like carbon (DLC) can be severly affected by the presence of zinc-dialkyldithiophosphate (ZDDP) additive in formulated oils. Tribological experiments show that DLCs friction and wear behaviour in the presence of ZDDP-additivated oils can be managed by tailoring their stiffness, surface nano-topography and hydrogen content. An optimal combination of ultralow friction and negligible wear is achieved using hydrogen-free tetrahedral amorphous carbon (ta-C) with moderate hardness. Softer coatings exhibit similarly low wear and thin ZDDP-derived patchy tribofilms but higher friction. Conversely, harder ta-Cs undergo severe wear and subsurface sulphur contamination. It appears that high local contact pressures caused by the contact stiffness and average surface slope of hard ta-Cs favour ZDDP fragmentation, inducing free sulphur release and its penetration in coating subsurface. Plastic deformation and the formation of graphitic regions and onion-like structures are observed in the weakened sulphur-rich zones by HRTEM[1].

The effect of sulphur element was further investigated by testing other sulphur-containing and sulphur-free additives. Similar tribochemical wear and high friction were observed for hard ta-Cs lubricated with Sulphur-containing molecules. On the contrary, no wear was observed with the sulphur-free additive. This work sheds light on the underlying micro/nano-scale mechanisms that are responsible for macroscopic tribological behaviour of DLC coatings lubricated in the presence of ZDDP and similar sulphur-containing additives.

Keywords: Friction, wear, DLC coatings, ZDDP additive, Tribochemistry.

[1] Valentin R. Salinas Ruiz, Takuya Kuwahara, Jules Galipaud, Karine Masenelli-Varlot, Mohamed Ben Hassine, Christophe Héau, Melissa Stoll, Leonhard Mayrhofer, Gianpietro Moras, Jean Michel Martin, Michael Moseler & Maria-Isabel de Barros Bouchet, NATURE COMMUNICATIONS (2021), https://doi.org/10.1038/s41467-021-24766-6.

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