# ZDDP Tribofilm Formation on Non-ferrous Surfaces

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Although a great deal of research has been carried out on ZDDP tribofilm on steel substrate, the understanding of tribofilm formation on non-ferrous substrates is limited. It has recently been shown that ZDDP tribofilms on steel can have either a nanocrystalline or amorphous structure and that tribofilms with a nanocrystalline structure are more durable than amorphous ones. This presentation describes the influence of rubbing material, including non-ferrous surfaces, on ZDDP tribofilm formation and investigates the relationship between tribofilm properties and durability on these surfaces.

**Keywords (from 3 to 5 max):** Non-ferrous material, ZDDP, tribofilm, adsorption

## 1. Introduction

The current trend for using lower viscosity lubricants with the aim of improving fuel economy of mechanical systems means that machine components are required to operate for longer periods in thin oil film, boundary and mixed lubrication conditions, where the risk of surface damage is increased. In addition, non-ferrous materials have been introduced in machine components to reduce wear and increase fuel efficiency. Thus, understanding of the zinc dialkyldithiophosphate (ZDDP) tribofilm formation mechanism on both ferrous and non-ferrous surfaces is increasingly important in order to formulate lubricants that give excellent antiwear performance on various material surfaces. In this study the effect of rubbing materials including ferrous and non-ferrous materials, i.e. steel, $Si_3N_4$, WC, SiC and a-C:H DLC coating on ZDDP tribofilm formation was investigated.

## 2. Methods

A mini traction machine (MTM) and an extreme pressure traction machine (ETM) ball on disc tribometer [1] were both employed to observe a ZDDP tribofilm growth in boundary lubrication and full-film EHD lubrication, respectively. Tribofilms on discs were analyzed using AFM, STEM-EDX and XPS. For further understanding of tribofilm formation, a quartz-crystal microbalance with dissipation monitoring (QCM-D) was used to monitor the adsorption of ZDDPs on to $Fe_2O_3$, $Si_3N_4$, WC, SiC and carbon coated quartz sensors.

## 3. Results and Discussion

Among non-ferrous materials, it was found that tribofilms were formed on $Si_3N_4$ and WC in the boundary lubrication regime measured by using MTM, but almost no tribofilms formed on SiC and a-C:H DLC (Figure 1). Although tribofilms formed on some non-ferrous surfaces, such tribofilms were easily removed by direct asperity contact because of weak adhesion of tribofilms to the substrate. This tribofilm removal makes quantification of ZDDP tribofilm formation on non-ferrous surfaces difficult. By contrast, in high shear stress EHL conditions, thick tribofilms formed without film removal in the order of steel > $Si_3N_4$ > WC, with no formation on SiC and DLC measured by using ETM. QCM results suggest that ZDDP tribofilm formation might be considerably affected by the extent to which ZDDP adsorbs on substrate surface (Figure 2). The chemical properties of tribofilms are discussed and a possible mechanism by which ZDDP forms tribofilm on non-ferrous surfaces is suggested. This study has practical implications for ways to protect non-ferrous surfaces from wear such as via lubricant formulation.

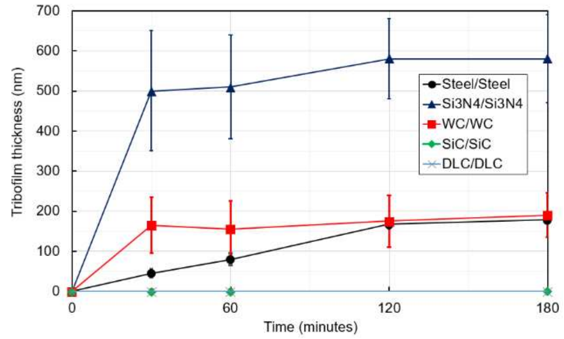


Figure 1. The evolution of ZDDP tribofilm thickness on each material during rubbing in thin film conditions.

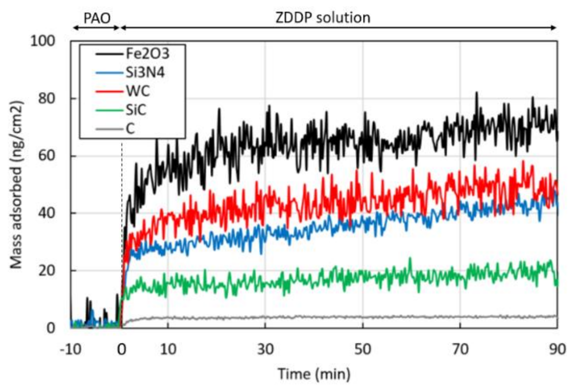


Figure 2. The evolution of ZDDP tribofilm thickness on each material during rubbing in thin film conditions.

## 4. References

[1] Zhang, J. et al., "Mechanochemistry of Zinc Dialkyldithiophosphate on Steel Surfaces under Elastohydrodynamic Lubrication Conditions" *ACS Applied Materials & Interfaces*, 12.5 (2020), 6662-6676.