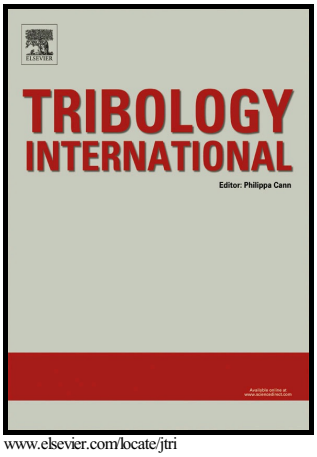

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PII: S0301-679X(16)30493-5
DOI: http://dx.doi.org/10.1016/j.triboint.2016.12.021
Reference: JTRI4505

To appear in: *Tribiology International*

Received date: 20 July 2016
Revised date: 17 November 2016
Accepted date: 13 December 2016

Cite this article as: M.L. Miranda-Medina, S. Spiller, A. Vernes and M. Jech, Spectroscopic ellipsometry and X-ray photoelectron comparative studies o tribofilms formed on cast iron surfaces, *Tribiology Internationa* http://dx.doi.org/10.1016/j.triboint.2016.12.021

Spectroscopic ellipsometry and X-ray photoelectron comparative studies of tribofilms formed on cast iron surfaces

M.L. Miranda-Medina[a*], S. Spiller[a,], A. Vernes[a,b] and M. Jech[a]

[a)] AC²T research GmbH, Viktor-Kaplan-Strasse 2, 2700 Wiener Neustadt, Austria
[b)] Institute of Applied Physics, Vienna University of Technology, Wiedner Hauptstr. 8-10/134, 1040 Vienna, Austria
[*]Corresponding author: maria.miranda@ac2t.at

Abstract

In this paper, tribofilms generated in a model piston ring –cylinder liner setup within a tribometer environment were investigated by optical techniques. The cylinder liner material was grey cast iron of an automotive grade, while the piston ring material was nitrided steel. X-ray photoelectron spectroscopy was used as a reference technique for estimation of thickness and chemical composition of the resulting tribofilms. Ellipsometrical measurements were modelled by using an effective medium approximation by including depolarisation effects to describe the optical constants of the tribofilm and to calculate the thickness and uniformity of the films. The adjustment of the effective medium on basis of the X-ray photoelectron spectroscopy findings resulted in a good agreement between the estimations for tribofilm thicknesses in both experimental methods.

Keywords: reciprocating sliding tribometer; ZDDP tribofilms; XPS; Ellipsometry

1. Introduction

The surface evolution during boundary lubricated sliding leads to formation of tribofilms that affect friction, wear and prevent large-scale damage of contact parts. Lubricants and especially engine oils use antiwear and antioxidant additives. Over seventy years, numerous studies have been performed on tribofilms formed by degradation of zinc dialkyldithiophosphate (ZDDP) additives . The current understanding of the structure of the ZDDP-induced tribofilms derives mainly from X-ray absorption near-edge spectroscopy (XANES), Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) techniques approached on the hard and soft acids and bases (HSAB) principle. The ZDDP tribofilm is described in the most of the models as a two-layer structure composed of inorganic polymer material. On the top surface, the long chain polyphosphate is a zinc phosphate and in the bulk, the short chain polyphosphate is a mixed Fe/Zn phosphate with a gradient concentration . The polyphosphate chains are partially adherent to steel surface through a sulfide layer , and work as anti-wear pads. The tribofilm properties e.g., chemical composition, chaining length, thickness, formation and durability depend on the wear test conditions. The tribofilm thickness is affected by the temperature, rubbing time, and surface roughness of the substrate. A rougher surface requires a longer time to form a tribofilm, while smoother surfaces favor decomposition of ZDDP and formation of long chain polyphosphate. However, thermal conditions and chemical reactions are the main factors involved in the performance of the tribofilm. High temperatures leads to thicker tribofilms with low