Self-lubricating W-S-C-Cr tribological coatings deposited by r.f. magnetron sputtering

Joao Vitor Pimentel[1*], Manuel Evaristo[2], Tomas Polcar[3], Albano Cavaleiro[2]

[1]Czech Technical University in Prague, Prague, Czech Republic

[2]SEG-CEMUC - Department of Mechanical Engineering, University of Coimbra, Coimbra, Portugal

[3]nCATS, Engineering Sciences, University of Southampton, Southampton, United Kingdom

[*]Corresponding author: j.v.bernatel@gmail.com

Introduction

Tribological coatings composed of transition metal dichalcogenides (TMD) have long been studied for their excellent self-lubricant properties. However, they exhibit low load-bearing capacity, and their performance tends to deteriorate significantly in the presence of humidity. In previous works, doping disulfides and diselenides of tungsten and molybdenum has proven to be a way of greatly improving the tribological performance of this class of films in different environments.

In this work, thin films were deposited by r.f. magnetron sputtering on silicon and steel samples, using two targets (carbon and chromium) and tungsten disulfide pellets. The final composition was controlled by the number of WS_2 pellets and the ratio of the power applied to the targets. The carbon content was fixed at approximately 40 at.% in all depositions. The chromium content in the coatings was varied in the range 0 – 13.5 at.% and the S/W ratio was approximately 1.25 in all compositions in the series. The coatings were characterized in regard to their hardness, adhesion, chemical composition and bonding, microstructure and morphology, as well as their tribological behaviour.

Characterization

Tribological tests were performed in humid air using a pin-on-disk tribometer. The applied contact load was varied and the wear tracks were examined, particularly by Raman spectroscopy and 3D profilometry. An adaptation of the equipment allowed the in-situ monitoring of the evolution of the wear tracks, by optical microscopy and Raman spectroscopy. The results of characterization and tribology evidenced improvements in hardness and wear resistance associated with the dopants.

Hardness values increased with Cr content, up to 7.1 GPa. With 0 at.% Cr (i.e., W-S-C only) the hardness was approximately 5 GPa, lower than that obtained previously with anther W-S-C system [1]. Nonetheless, these results evidence an improvement of more than one order of magnitude compared to undoped WS_2 films and are consistent with previous studies on doped TMD films [1,2].

The friction coefficients decreased with increasing load, indicating that the sliding under high contact pressure leads to the formation of a TMD-rich tribolayer. Raman spectroscopy showed a clear decrease in the contribution to the spectra of peaks corresponding to carbon. Analyses of the wear tracks indicated that the tribolayer consisted mainly of amorphous tungsten and chromium oxides with platelets of WS_2 in small areas. Below the outermost surface, however, a thin layer of well oriented WS_2 was found at the interface between tribolayer and coating [3].

The in-situ analyses yielded interesting results regarding the tribolayer formation during running-in and the sliding process. Although it was not possible to carry out a full measurement of the wear track profile, the optical analysis showed that the wear track widened rapidly in the first tens of cycles. By the 100^{th} cycle, the width of the wear track was already about 90% of the final width at steady state.

It was also observed during running-in the formation of rather large particles of debris, as well as scratches produced very early on which remained for tens of cycles or more. In some cases, we were able to directly relate events in the friction curves with the presence of large debris or localized spots where the film was worn out. In previous studies with TMDs and results obtained with patterned samples (yet to be published), we have found that small areas where the substrate is exposed are very often filled up with tribomaterial during the sliding process, in a self-healing process.

References

[1] J.V. Pimentel, T. Polcar, M. Evaristo, A. Cavaleiro, Tribol. Int. 47 (2012) 188-193.

[2] T. Polcar, A. Cavaleiro, Surf. Coat. Technol. 206 (2011) 686-695.

[3] T. Polcar, F. Gustavsson, T. Thersleff, S. Jacobson, A. Cavaleiro, Faraday Discuss. 156 (2012) 383-401.

Figures

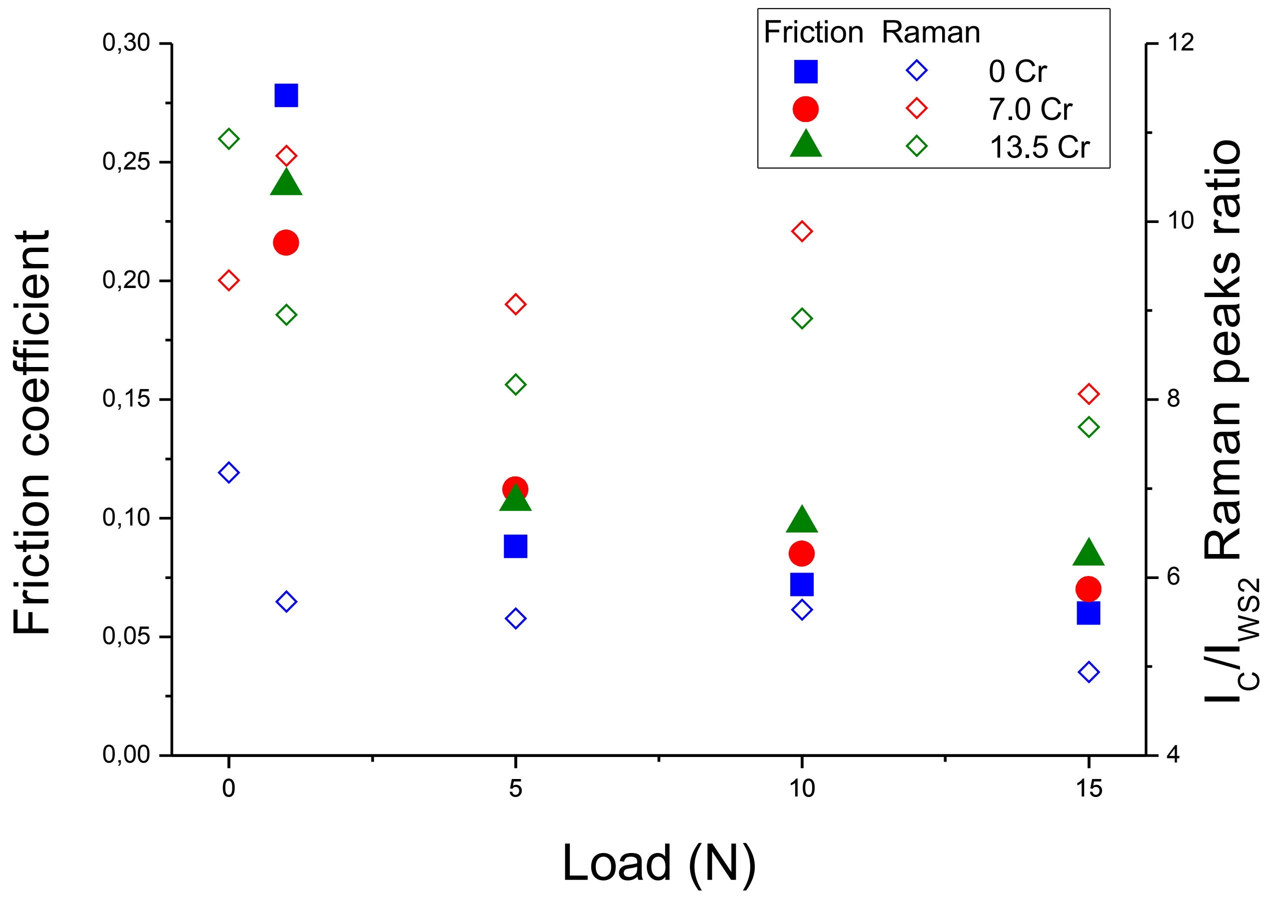

Fig. 1 Friction coefficient and Raman peak ratio for different loads

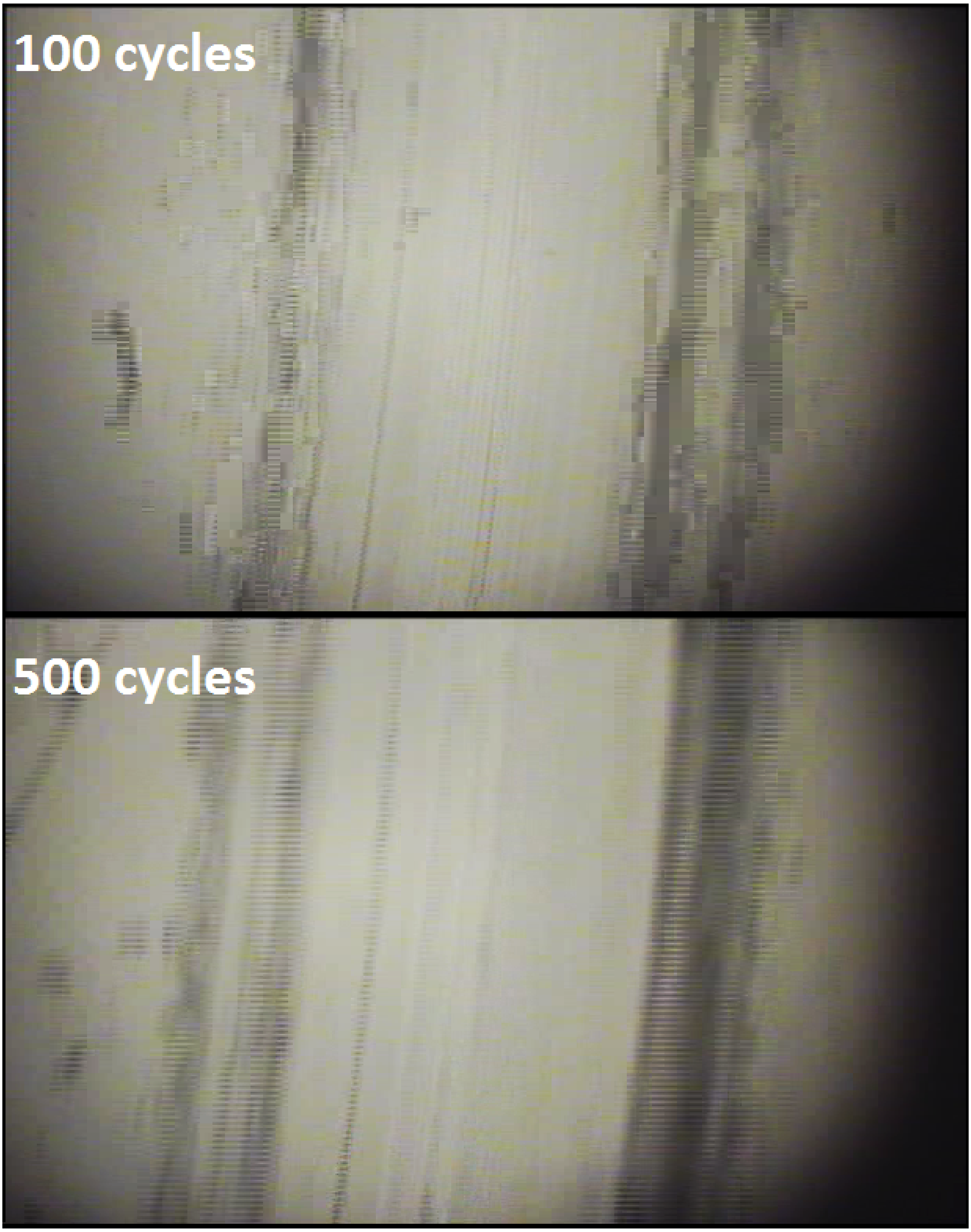

Fig. 2 Wear track during sliding, after 100 (above) and 500 cycles (below).