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Formation of a conductive tribopolymerized third body in a silicone-lubricated polymer-metal electrical contact: mechanisms and consequences

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Electrical components are made of conducting materials but the third body made of their wear debris may be insulating if e.g. metallic debris are formed and oxidized. Another key point is whether such insulating debris remain in the contact or are expelled from it. One of the third body formation mechanisms, tribo-polymerization of lubricant components, can also form an obstacle to electric conduction. In the silicone-lubricated conducting polymer-metal system addressed here, a tribopolymerized silicone 3rd body forms. Yet its resistance remains sufficiently low that the application is not disturbed. AFM / Resiscope® measurements show this to be due to the simultaneous ingestion of conducting C-filled polymer wear debris, providing a sufficient number of conductive spots through the film.

Keywords: electrical contact, third body, silicone, tribopolymerization

The studied device is an electric potentiometer-based position sensor consisting of a low pressure sliding contact between a 4-wire noble metal (AgPd-based) contactor ("cursor") and a resistive track made of a 30% carbon-filled thermo-setting resin. The contact is lubricated with a silicone oil / PTFE grease operating under boundary lubrication to ensure low electrical contact resistance. During service, 4 "glossy layers" (GL) form systematically on the polymer track below each wire of the cursor; yet the contact resistance remains below 500 Ω, allowing nominal function of the sensor. The nature and formation mechanisms of the GL have been studied to weigh the risk associated with it.

According to SEM observations, the GL is formed of irregularly dispersed solid particles. EDX analysis performed on the thicker areas of the GL display mostly Si and F, the characteristic elements of the lubricant. The tape adhesion test proves those particles quite adherent, except on the edges of each contact area.
XPS analyses (Figure 1) show that compared with the virgin grease, one more contribution appears on GL's spectrum at higher binding energies (Contribution B). According to Hirahara et al. [2], the "SiO_2" contribution B (103,4 eV) betrays partial oxidation of O-Si$(CxHy)_2$-O (Si^{2+}) of silicone oil into O-Si(C_xH_y)(O)-O (Si^{3+}) and O-Si$(O)_2$-O (Si^{4+}): bridges appear between initially linear macromolecules ("gelification"), which is a tribo-polymerization. This mechanism has been first pointed out for silicone oils by Tabor and Willis, influenced by temperature (~100°C) and oxygen, and triggered by Cu catalysis in their case [3]. Here, it is thought that the presence of known catalyst metals (Ag, Pd) might cause the same reaction at lower (room) temperature.
Finally, electric "screening" tests (abridged, laboratory-simulated life cycle of a sensor) prove contact resistance stays within tolerance. An AFM + Resiscope® study has been performed to characterize electric contact spots. They are similar in size, shape and density to conductive C-particles initially included in polymer track resin. It is concluded that wear debris formed in the initial stage of the screening test are integrated in the GL and provide enough contact spots to preserve contact conductance.

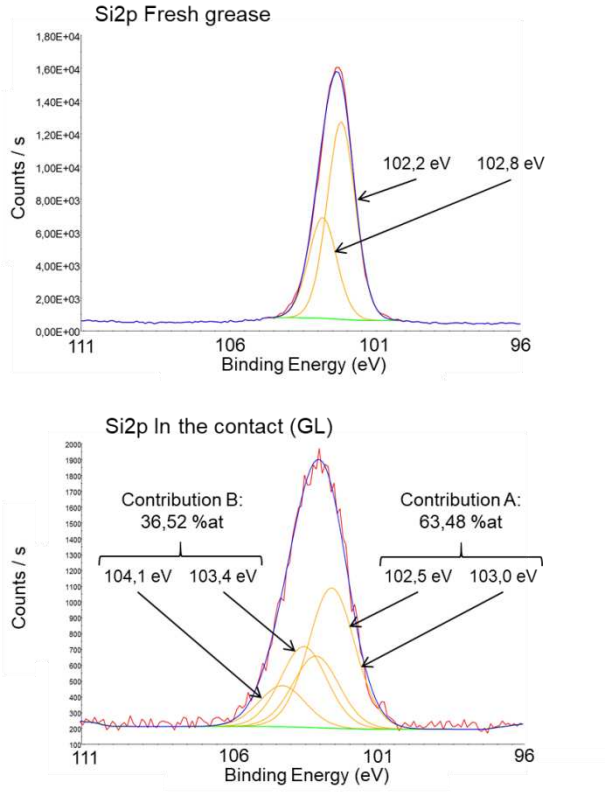

Figure 1: compared XPS Si2p spectra in the grease and in the GL, showing peak widening by a second contribution at higher binding energy.

References

[1] N. Saka, et al., "The role of tribology in electrical contact phenomena," Wear, 100, 1984, 77–105
[2] H. Hirahara, et al., "Adhesion between cured silicone rubbers," Int. Polym. Sci. Technol., 41, 2, 2014, 21–26
[3] D. Tabor, R.F. Willis, "The formation of silicone polymer films on metal surfaces at high temperatures and their boundary lubricating properties", Wear, 13, 1969, 413-442