Effect of environment gaseous contamination on dry lubrication – In space applications –

Subject

A few recent studies showed that low particle generation and extremely low friction can be the result of a complex mechanically activated chemical reactions between the materials in contact, its internal and external (from the gaseous environment) contaminants [1–3]. Such phenomenon can literally turn non-lubricious interface into lubricious ones, friction coefficient can be reduced by a factor of 10 to reach a coefficient of 0.02[3]! Interestingly, only traces (down to ppm and ppb levels) of airborne molecular contaminants (AMC) are sufficient to initiate the creation and the maintaining of this lubricious interface [3]. In such process, reaching steady state the friction coefficient happens quickly (within a few cycles) [3,4] while resulting in very limited wear, see no wear at all [4]. Such a behavior has been observed with low amounts of C in MoS_2 coatings and water adsorption in moderate vacuum [1], with elements of the base material such Ti from MoS_2+Ti coating in dry N_2 environment [1], Pt and Au from the Pt/Au nanocomposites in dry N_2 environment contaminated with ~100ppb Volatile Organic Compounds (VOC) [3], and with residual elements (Si<1%w from Z100CD17 steel [4]). Furthermore, as shown with MoS_2 and DLC in dry N_2 environment [1,5], physisorption of gas can lower friction and wear, without implying tribochemical events.

Over the years, MoS_2 and metal-doped MoS_2 (space lubricants) has been showed to demonstrate gas sensing capabilities to CO, CO_2, NO, NO_2, NH_3, H_2O from sub ppm to 100s ppm level [6,7], meaning it is sensitive to their adsorption. Moreover, MoO_3, well known oxide that can be created from MoS_2 through friction, also demonstrates gas sensing capabilities, to ethanol for example. Satellite are tested in clean room environments (VOC, humidity, etc), simulated vacuum environments (moderate and high, mostly comprised of water), and then in the vacuum of space. However, the close environment of a satellite in space is very different form the space environment: higher vacuum pressure (10^{-5}mbar inside the satellite) and contaminated molecular composition (outgassed products, water, hydrocarbons, propellant residues, etc).

Considering (i) such sensitivity to contamination, (ii) the real satellite close environment, and (iii) the evidence of significant but potentially beneficial effect of traces of contaminants on the tribological of materials (lubricious and none lubricious), studying the effect of contamination on lubricant in space lubrication is critical to better predict the real behaviour of the lubricants, and of the mechanisms.

The proposed study aims at studying the effect of AMCs on the tribological behaviour of an MoS_2 based lubricant and metal oxide-based coating: MoO_3 and WO_3. MoS_2 based lubricant and MoO_3 are obvious (cf. above). WO_3 oxide is very interesting because it demonstrates sensitivity to airborne contaminants such as ozone, and dodecane [8], in concentration similar to the air environment up to 100s of ppm. It has also been shown sensitive to CO/CO_2 [9]. Stoichiometric WO_3 oxide is not lubricious, however when it is in the form of magneli phase, it can demonstrate lubricious properties [10]. Our recent work on SnO_2 oxide vs ethanol contaminated environment (1000ppm) showed that lubricity and antiwear properties can be achieved, even for such non-lubricious metal oxide. All deposition machine to accurately control WOx composition are available in house at FEMTO-ST, as well as set-ups on site to control contamination in the range from 10 ppb to 1000ppm at atmospheric pressure and adaptable to tribometers, but also UHV tribometer equipped with microleak valve to control vacuum contamination. Vacuum and atmospheric tribometers are equipped with mass spectrometer to monitor contamination level, including the contamination induced by friction. In depth analysis of friction materials will be conducted.

The overreaching goal is to understand the tribological behaviour of the materials in contaminated environment representatives of space related applications (on Earth and in space). The study may also provide a new avenue for the development of lubricious materials for space applications, but also for planet and natural satellite explorations. Final selection of materials to be studied, contaminant selection, and contact conditions will be defined with CNES and co-funding partner.

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Information

Partners: The PhD thesis is a **collaboration** between the **French Space Agency** (**CNES**, *https://cnes.fr/fr/*), **ADR Alcen** (*https://www.adr-alcen.com/en*), and **Institut FEMTO-ST** (*https://www.femto-st.fr/en*), under CNES PhD program.

Location: FEMTO-ST Institute, Besançon, France, in the Micro-Nano Sciences and Systems Department (MN2S). The MINAMAS (Micro-Nano Materials and Surfaces) team specializes in the physical, and tribological study of thin films, nanomaterials and solid/gas interaction. It has developed strong expertise in multi-environment lubrication, and nanomechanical characterization of tribological materials, particularly for space mechanisms. **Starting date**: October 2024

Application: online on https://recrutement.cnes.fr/fr/annonces from February 1st to March 15th, 2024, subject REF : 24-129

Contact for information request: Dr. Guillaume Colas (Institut FEMTO-ST, Besançon, France) guillaume.colas@femto-st.fr