- PhD Thesis -

Optimization of self-assembled multilayer in the lubrication of space mechanisms

The development of lubricants for space applications is a highly specialized challenge given the mechanical and physicochemical environments in which the mechanisms operate. Whether on the ground, in air, in a vacuum, in a thermal vacuum, or in space, the systems operate in a succession of extreme environments.

A range of lubricants already exists, each with different specificities and different fields of application: fluid lubrication (oils) for systems operating at relatively high speeds within a limited operating temperature range, greases for lower speeds or when oil migration can be problematic, solid materials (burnished deposits, PVD deposits, self-lubricating composites) for low speeds and very wide temperature ranges, etc. All these solutions involve recurring constraints such as: (i) maintaining performance in different environments, particularly air and vacuum, (ii) ease of application and associated cost, (ii) thickness management in preload calculations.

In order to meet these constraints, we proposed during the Surface Functionalization R&T Challenge (2023–2024) to test a lubricant that works at the molecular level and can be applied by simple spray. Initially developed to lubricate contacts subject to high mechanical stress, particularly in deep drawing operations, this lubricant's performance increases with increasing contact pressure. From its manufacture to its use, the product is eco-friendly, meeting the constraints imposed on the toxicity of products used in lubrication.

The study demonstrated the lubrication capabilities of metal/metal contacts with moderate to average service life, with a friction coefficient consistently between 0.03 and 0.1, in pure sliding and rolling-sliding kinematics [1]. Friction in vacuum proved to be more stable than in air, although performance in air remained very good. In terms of friction performance, it proved to be equivalent to that of a conventional MoS2 coating in vacuum. Finally, performance improves as contact pressure increases. Under friction, the molecules appear to transform into a nanometric layer with spectral signatures of turbostratic carbon and hydrogenated graphene oxide, thereby lubricating the contact. As this range of materials is temperature-stable, it offers interesting prospects for use in space applications.

However, the study shows that the coating is comprised of molecule agglomerates distributed evenly across the surface, which leaves regular spaces in-between. These agglomerates can be easily removed by the ball rubbing against them. This implies a limited lifespan in the case of reciprocating friction kinematics. There also appears to be a low sensitivity to humid environments, and a relative sensitivity of the friction response to the rigidity of the tribological systems.

The objective of this project is to optimize the deposition of molecules and the formation of self-assembled layers in order to obtain a homogeneous, chemisorbed molecular coating over the entire surface of the substrate. The quality of the deposition must be assessable using a simple technique such as fluorescence. While maintaining a maximum thickness of 300 nm, the lubricant must provide at least the same performance as the film deposited by spray and formed from agglomerates.

Analysis tools such has Raman Spectroscopy, XPS, and FTIR spectroscopy will be used. Once homogeneity is achieved, series of tests will be carried out in the laboratory in different environments (humid air, vacuum, nitrogen), in a temperature range covering a maximum of -120°C to +120°C, under different contact pressures. Mechanisms of the friction induced transformations will be investigated using spectroscopy et spectrometry technique. Reaxff Molecular dynamic simulation is also considered to study fundamentally the mechanisms involved friction induced transformations.

Ultimately, tests on actual components will also be carried out at the partner's premises, mainly involving tests on bearings with coated tracks. A comparison between the original sprayed coating and the homogenized one will be carried out. Studies conducted on dry lubricants as part of related studies will also serve as points of comparison. The student will work both in the laboratory and at the co-financing industrial partner's premises.

[1] G Colas, et al. Lubrication by self-assembled multilayer _ New avenue for low cost lubrication alternative to MoS2. ESMATS 2025, https://www.esmats.eu/esmatspapers/pastpapers/pdfs/2025/colas_v2.pdf

Information

Partners: The PhD thesis is a **collaboration** between the **French Space Agency** (**CNES**, *https://cnes.fr/fr/*), **CIPELIA's subsidiary companies INS** (https://ins-sciences.com/) **and UnilOPAL** (https://www.unil-opal.com/)**,** 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.

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Application: online on https://recrutement.cnes.fr/fr/annonces from **February 2nd to March 13th, 2026, subject REF : 26-159**

CV, cover letter, recommendation letters, and trasncripts are requested

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