Surface Engineering Meets Tailored Nanoparticles – Ways to Optimize the Frictional Performance

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Introduction

In a world with a continuously increasing energy demand and diminishing oil resources, it becomes important to tackle problems related to friction and wear thus improving the respective energy efficiency [1,2]. Considering cars, friction and wear greatly contribute to an increased fuel consumption, diminished energy efficiency and shortened components’ lifetime. It can be estimated that friction and wear losses can be reduced by about 60% when using modern surface engineering, advanced coatings’ systems, new lubricants or tailored solid lubricants, which would tremendously impact the resulting energy efficiency, fuel savings and finally the environment due to reduced CO₂-emissions [1-3].

In the 20 years, considerable effort related to surface engineering, particularly, laser surface patterning has been dedicated to tailor friction and wear under dry and lubricated conditions [4-6]. In this context, direct laser interference patterning has demonstrated its significant potential to be effective under dry friction and different lubricated conditions ranging from boundary, over mixed to electrohydrodynamic conditions [7-11].

Apart from surface texturing, the use of nanoparticles either as a lubricant’s additive or solid lubricant has shown tremendous potential to manipulate tribological properties. The discovery of graphene with its remarkable physical properties can be considered as the initiation of numerous research endeavours in this field [12,13]. Apart from graphene and graphene oxide, the carbon family offers a variety of nanoparticles such as carbon onions (purely sp²-hybridization) or nanodiamonds (purely sp³-hybridization) with very attractive frictional properties [14-16]. Regarding carbon onions and Nano diamonds, the frictional properties can be tuned through the adjustable sp²-sp³ ratio, which can be easily manipulated by thermal annealing [14,17].

Using these tailored nanoparticles can be either beneficial in terms of friction or wear depending on the adjusted sp²-sp³ ratio. In this sense, a higher amount of sp²-carbon may be more beneficial to induce a certain friction reduction, while a higher sp³-content can be very promising for a superior wear resistance. This allows for the tremendous potential to adjust the respective property (friction, wear or a compromise) depending on the corresponding tribological system.

Besides the carbon family with its numerous members, the family of 2- or 3-dimensional nanomaterials has been significantly expanded by the early transition metal carbides and/or carbonitrides based upon MAX-phases and named as MXenes. MXenes are generally synthesised by removing the A layers of Mₙ₊₁AXₙ (M: early transition metal, A: group IIIA or IVA element and X: C or N with n=1, 2 or 3) using selective etching [18,19].

MXenes are particularly interesting for tribological purposes due to their layered graphite-like structure, low shear strength and self-lubrication ability, which has already been numerically confirmed by density functional theory and molecular dynamic simulations [20,21]. Although bearing tremendous potential, the usage of MXenes in tribology is surprisingly underexplored. Moreover, MXenes offer the possibility to adjust their surface chemistry due to the significant number of functional groups available at the surfaces and interfaces. These functional groups contain typically -O, -OH and -F-groups, which can be perfectly used to act as binding elements for further surface functionalization [22].

In this context, the surface functionalization of MXenes can open new doors to optimize their materials behaviour in various fields such as tribology, energy, catalysis, water purification, among
others. Therefore, it is straight-forward to imagine that function-
alized Mxenes and/or other 2-dimensional nanoparticles bear the
enormous potential to provide new solution strategies to tackle the
aforementioned problems and issues related to global warming and
increasing energy demand.

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