Analysis of the mechanical and chemical wear components by combining multi-asperity nanotribology and discrete numerical simulation

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Wear can be described as a process which involves mechanical and chemical phenomena at various scale levels [1]. Extracting each sort of components should enable to better understand wear mechanisms from the macroscale down to the nanoscale and the atomic level.
However, it is well known that these components are generally hard to extract independently because their own time responses are generally not in the same order [1, 2]. Mixing chemical reactions and mechanical deformations in a same model is quite difficult to carry out, whereas they work together rather well in the real world. A suitable approach is to combine experimental multi-asperity nanotribological tests and numerical simulations using discrete elements, which are able to interact together within the contact. Experimental tests enable to control the actual chemical environment [1], and numerical simulations give the opportunity to access to the hidden parameters controlling agglomeration and fracture mechanisms of particles which are trapped within the contact [2, 3].

In this work, experimental tests are carried out using a ball-on-disc nanotribometer *CSM Instruments (Switzerland)* in linear reciprocating mode, in dry conditions at room temperature, under controlled environment by using a glove box [4]. The ball (100Cr6 or Si_3N_4) is loaded onto a flat sample with a precisely known force using closed loop. The friction force is determined by measuring the deflection of an elastic arm designed as a frictionless force transducer (resolution: 1µN). Slider's depth is accurately assessed in real time for studying any time-dependent wear process and/or potential build-up of a *tribolayer* within the contact [4]. *Friction* and *Depth maps* are simultaneously plotted as a triboscopic approach [4]. For this purpose, a specific methodology has been developed for extracting an actual *Wear map* from the initial *Depth map* by considering both the tilt and the initial deformation of the samples [5]. Finally the wear profile – *ie*, wear depth *vs.* time – is directly extracted from the actual *Wear map* [5].

These experimental tests are then coupled with a numerical approach simulating a multi-asperity nanotribological contact using *Movable Cellular Automata*, where interactions between automata pairs are controlled by various fracture and bonds formation criteria [3]. Hence, evolutions of the friction coefficient and wear profile can also be plotted for various interactions criteria configurations. Trying various sets of interaction's criteria, there is generally an optimal set which provides numerical results which are well matched with the experimental results. Thus, by studying the influence of experimental environment on this optimal set, various assumptions can be made about chemical and physico-chemical phenomena that are likely to occur within the actual tribocontact.
These assumptions will be studied for various samples – *ie*, silicon wafers displaying various crystallographic orientations and roughnesses, carbon nitride coatings, and self-assembled monolayers grafted on silicon wafers – rubbing under different environmental conditions.

References

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