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TRIBOACTIVE SURFACES IN MULTI-ASPERITY NANOTRIBOLOGY

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ABSTRACT

Friction and adhesion phenomena in microsystems (MEMS) need to be accurately controlled but with a MEMS design which has to be as simple as possible [1]. An interesting way is to design specific surfaces – so-called *triboactive* – whose frictional behavior can be controlled in real time by using external stimuli, as temperature, UV, electric or magnetic fields etc [2]. Frictional behavior occurring in air is generally influenced by two different components, which could be controlled separately [3]:

- (i) the *physico-chemical* one, which can be driven by creating patterned surfaces whose the adhesion behavior is likely to be predicted by means of wettability models [4];
- (ii) the *mechanical* one, of which there are not accurate predictive models [3]. Hence, an alternative way consists of grafting stimuli-driven self-assembled monolayers (SAM) on the rubbing surfaces [5];

In this work, *n*-octadecyltrichlorosilane (OTS) have been grafted on various micro-pillars created by Deep Reactive-Ion Etching (DRIE) of silicon wafers. This multi-architectured surfaces have then been tested with a *ball-on-disc* nanotribometer CSM Instruments (F_n: 3 mN, ball: Si_3N_4 ∅ 1,5 mm) working in linear reciprocating mode, under various environmental conditions. Whereas the pillar's height is always fixed at 10 µm, their shapes and pitches are changed in order to test various wettability models – as *Cassie-Baxter* or *Wenzel* ones [4]. The Cassie-Baxter model can be applied in the densest pillars' area while the Wenzel one matches with weakest pillar's area. Since the frictional behavior of OTS monolayers is known to be thermally sensitive, the temperature of the structure is imposed during the tribological test by using a Peltier module.

Results reveal that the frictional behavior can be accurately controlled in a range of 0.1 to 0.04 by simply varying the temperature from 0 to 80°C. This decrease is mainly due to a reversible increase of disorder (or entropy) within the monolayer [3], without any degradation in this range of temperatures. On the contrary, silicon micro-architecture quickly suffers wear by a shearing process at the bottom of the pillars whatever the DRIE pattern design. The structure's degradation process has been studied with a finite element model on ABAQUS. This process can be attributed to an additional adhesion force in the Cassie-Baxter's area and to an increase of the contact pressure on each pillar in the Wenzel's area.

In order to keep the thermal ability to control the frictional behavior without suffering any wear process, same kinds of patterns are then created on silicon by using micro-contact printing process instead of DRIE [7]. This approach is a soft lithography that uses the relief patterns on a master polydimethylsiloxane (PDMS) stamp to form patterns of self-assembled monolayers (SAMs) as ink on the surface of the silicon substrate through conformal contact.

As a result, nanotribological testings reveal that the wear process of the nano-printed surfaces is strongly reduced in regard to above one. In addition, it can be highly reduced by controlling the printed pattern while the frictional behavior is always thermally-controlled. Hence, a new wear model of SAMs which takes into account the pitch of the printed pattern will be presented and discussed.

REFERENCES

[1] E. Gnecco, E. Meyer, *Fundamentals of Friction and Wear on the Nanoscale*, Springer, 2007, 714p ;

[2] Ph. Stempflé, J. Takadoum, Tribology Int 48 (2012) 35–43;

[3] Ph. Stempflé et al, Tribology Int. 82 (2015) 358–374;

[4] B. Bhushan, Y. C. Jung, Progr. in Materials Science, 56 (2011) 1-108;

[5] A. Domatti et al, Tribol Lett (2013) 51:207–218;

[6] J. Barriga et al, Tribol Int 40, (2007);960–6

[7] J. Bennès et al, Appl. Surf. Sci., 255, (2008) 1796-1800