Multi-asperity nanotribometer and quartz crystal resonator *in situ* measurements for studying the sliding threshold at the nanoscale

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Abstract

Multi-asperity nanotribology is frequently met in MEMS/NEMS where tribological behavior is completely controlled by interactions between nano-asperities. Understanding the local phenomena that occur within the current tribocontact would enable to design surfaces whose frictional behavior can be controlled in real time, by means of external stimuli [1]. In this work, a multi-asperity nanotribometer CSM Instruments (Switzerland) has been modified for working in conjunction with an AT – cut Quartz Crystal Resonator (Novatech, Italy) as a flat sample. Thus, a rough PDMS ball (Ø 5 mm) is glued on the nanotribometer's stiff lever – designed as a frictionless force transducer – and loaded onto the resonator with a precisely known force using closed loop. Two kinds of tests have been carried out in order to find :

- First, the relationship between the *real contact area – ie*, the number of asperities really in contact – and the *acoustic transmittance* by only varying the applied normal load without any sliding. The measured frequency shift is around of 1 Hz/mN for PDMS/Gold. This value is very close to the ones computed by using multiphysics FE simulations calibrated with a MEMS analyzer. The relationship between the *real contact area* and the *frequency shift* is finally computed using a JKR model as proposed by Flanigan *et al* for PMMA [2].
- Second, the influence of the *sliding amplitude* on the *acoustic transmittance* as a function of the *real contact area*: (i) the acoustic transmittance only tracks any change in the *real contact area* as a movement of asperities when the imposed *sliding amplitude* is lower than the contact radius. So, typical shifts stay in between 4 to 9 Hz depending of the lateral velocity (µm/s) for a constant normal load fixed at 10 mN ; (ii) the *sliding threshold* can clearly be assessed in term of acoustic transmittance as soon as the imposed sliding amplitude is greater than the contact radius ; Thus, *slip time* variations can be computed for various tribological parameters (eg. normal load, sliding velocity) by simultaneously assessing the *frequency shift* and the *dissipation parameter* which is connected to the variations of *quality factor,* as demonstrated by Krim *et al* [3]. In this case, any dissipation at the *ball/electrode* interface leads to *stick-slip* phenomena at the asperities' level.

Finally, these results clearly reveal the difference – in term of *acoustic transmittance* [4] – existing between the various dissipative components that are likely to be involved during friction – *ie*, real contact area modification, sliding threshold and dynamic sliding.

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