Understanding Friction Elementary Mechanisms at the Nanometer Scale

The comprehension of friction mechanisms at the nanometer scale, known as nanotribology, is of huge interest for both scientific and technologic fields. On the fundamental side, friction is a phenomenon that is manifested in many natural behaviors such as earthquakes, landslides and granular physics. On the technological side, the emergence of miniaturized mechanical systems and nanotechnologies requires reducing friction in order to improve the system autonomy, durability, and to minimize their economical and environmental costs. However, phenomena involved in friction mechanisms are far from being well understood. The main reason is that the nature of the contact is not well defined. The development of Atomic Force Microscopy (AFM) offers new opportunities for a better understanding of the elementary mechanisms of friction at the nanometer scale. The principle of an AFM is to scan the sample surface with a sharp tip (tip radius about 10 nm), with a back and forth displacement, while measuring the normal or friction forces between the tip and the sample. For tribological experiments, it offers the possibility to generate a well-defined mono-asperity contact between the AFM tip and the sample.

Recently in the Laboratoire Roberval of the University of Technology of Compiegne (UTC)), we have modified a conventional AFM to implement two new AFM modes called initiation of sliding (Fig.1) and circular mode (Fig. 2) (Int. patent UTC-IMMM Le Mans). The principal is to impose either a one direction oscillating or either a circular relative displacement of the AFM tip in the plane of the sample. Compared to conventional AFM modes, our original experimental set-up have many advantages for tribological experiments. In particular, it allows acquiring instantaneously and accurately friction forces as a function of the load (at constant sliding velocity) or friction force as a function of the sliding velocity (at constant load) allowing measurement of relation between adhesion, friction and wear [1-5].

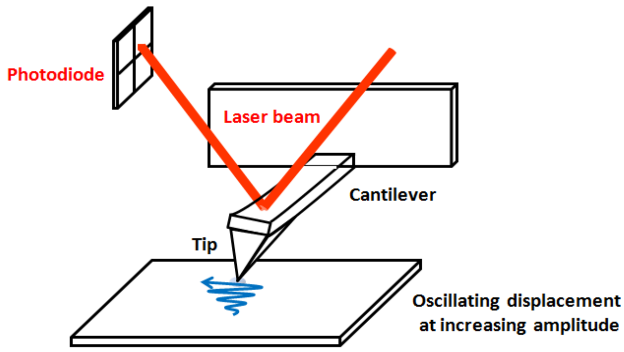

Fig. 1: Initiation of sliding. The tip is in contact with the sample and animated by a sinusoidal displacement of increasing amplitude. The experiment allows exploring the transition between shear of the contact and sliding at increasing sliding velocity.

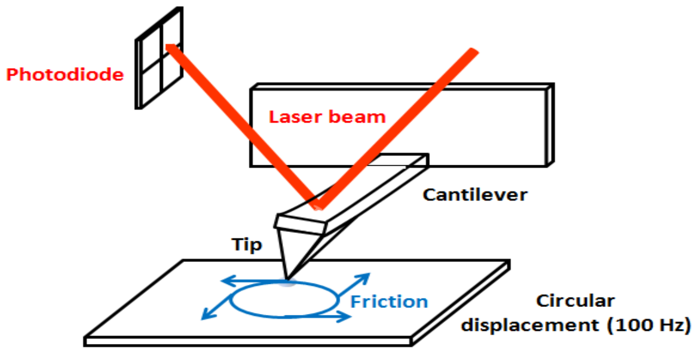

Fig. 2: CM-AFM. The tip is in contact with the sample and animated by a circular displacement. Normal and friction forces generate flexion and torsion of the cantilever that are detected by the deviation of the laser beam leading to the simultaneous measurement of the normal and friction forces.

The objective of this PhD is thus:

- To use these two modes to explore the tribological behaviors of model contacts and more precisely, to study the influence of sliding velocity on friction and adhesive forces.
- To describe and explain the evolution of the tribological laws as a function of the experimental conditions (nature of the material, % humidity…)
- To compare experimental laws with theoretical models

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[3] Nasrallah, H., Mazeran, P.-E., Noël, O., *Circular mode: A new AFM mode for investigating surface properties,* **Review Scientific Instruments**, 82 (2011) 113703

[4] Noel, O., Mazeran, P.-E., Nasrallah, H., *Sliding velocity dependence of adhesion in a nanometer sized-contact,* **Physical Review Letters**, 108 (2012) 015503

[5] Noël, O., Vencl, A., Mazeran, P.-E., *Exploring wear at the nano-scale with the circular mode AFM*, **Belstein Journal of Nanotechnology** (2017)