20aE-06
International Tribology Conference, TOKYO 2015
September 16th – 20th, 2015, Tokyo, Japan

Circular Mode AFM: a new mode for investigating nanotribology

Olivier Noel[1)]*, Pierre-Emmanuel Mazeran[2], Karim El-Kirat[3], Hussein Nasrallah[1], Alelksandar Vencl[4], Kamil Kluza[5]

[1)]Institut des Molécules, Matériaux du Mans (IMMM), UMR CNRS 6283, Le Mans, France
[2)]LaboratoireRoberval, UMR CNRS 7337, UTC, Compiègne, France
[3)]Laboratoire de BioMécanique et BioIngénierie, UMR 7338, UTC, Compiègne, France
[4)] Tribology Laboratory, Faculty of Mechanical Engineering, University of Belgrade, Serbia
[5)]University of Katowice (Master Student C-Nano), Poland

*Corresponding author:olivier.noel@univ-lemans fr

Keywords: Nano-tribology, Atomic Force Microscopy (AFM), NanoMetrology, Biotechnology, Wear and Instrumentation

1. Introduction

The elementary mechanisms of friction at the nanoscale are still poorly understood. One of the main reasons is that the geometry of the contact between the two surfaces in sliding is not really controlled and well defined.

In the last decades, the Atomic Force Microscope (AFM) allowed measuring adhesive and friction force at the nano-scale with a high resolution in a well-defined mono-asperity contact formed by the AFM probe and the surface of the sample. However, the measurements of the friction forces using the commercial AFM modes consists in measuring the torsional signal of the cantilever while applying back and forth scanning of the AFM probe in contact with the sample. In these conditions, the sliding velocity of the probe in contact with the sample is not constant as the sliding velocity goes to zero when the probe changes its sliding direction. Moreover, the change of direction also generates stop periods. Thus, the friction force measurements are not carried on in a stationary regime. Therefore, time dependent mechanisms such as the formation of a capillary meniscus between two hydrophilic surfaces in sliding or viscoelastic behavior may affect the measurements in using conventional AFM modes and this may lead to misinterpretations. Here, we describe the principle and the applications of a new AFM mode, called the Circular Mode AFM (CM-AFM) [1] to measure nano-tribological properties in a sliding nano-contact.

2. Principle of the CM-AFM [2]

In the CM-AFM, the electronic of a conventional AFM has been modified to impose a circular displacement to the probe in contact in the plane of the sample. In these conditions the sliding velocity of the sliding nano-contact is constant and continuous. No stop periods occur during the measurement and a stationary regime is reached. Moreover, the sliding velocities that are generated with the CM-AFM are comparable to those that are used in industrial and technological applications (> 1 mm/s). Technically, the torsional signal of the cantilever at the sliding frequency is a sinusoidal signal which amplitude measured by a lock-in amplifier gives directly the value of friction force between the probe and the sample. Coupled to the conventional force mode (i.e we simultaneously impose a vertical displacement to the probe), it is possible to measure the adhesion force in a sliding nano-contact and to get instantaneously the friction force law and an estimation of the friction coefficient.

	Conventional Mode	CM-AFM
Accessible Data	**Classical Data such as:** -Adhesion Force, - Friction Force in a non–stationary regime	**Classical Data obtained in a stationary regime** + -Instantaneous friction law -Friction coefficient -Both adhesion force and friction force spectra
Solicitation velocity	Low scanning or sliding velocity (maximum 1µm/s)	High scanning or sliding velocity (> 1mm/s)

Table 1: Access data obtained by conventional AFM Mode vs. CM-AFM

3. Applications of the CM-AFM mode

The CM-AFM is useful and is more advantageous as conventional Modes for applications in NanoMetrology, Nanotribology, Wear, Biotechnology (it may be used in liquids), Polishing, and Nanolithography.

4. References

[1] H.Nasrallah, P-E Mazeran, O.Noel, Circular mode: A new scanning probe microscopymethod for investigating surface properties at a constant

and continuous scanning velocities, Rev. Sci. Instrum. 82, 113703 (2011).

[2] O. Noël, P.E. Mazeranet H. Nasrallah, CM-AFM Patented by the CNRS PCT/FR2011/051024; Japanese Patent JP2013-508547; US Patent No. 13/695 685.