PHD Position

TITLE

Multi-asperity nanotribology in air and vacuum: development of new devices for friction and adhesion characterization, and for analysis of controlled triboactive surfaces.

Associated FEMTO-ST departments
Micro Nano Sciences and Systems Department (MN2S).
Automatic Control and Micro-Mechatronic Systems Department (AS2M).

Context

Currently, friction and wear processes of small contact surfaces met in micro-mechanical devices (so-called MEMS) are still largely misunderstood. Indeed, designed to small tolerances, reliability of MEMS devices (comb drives, current grippers and future dextrous grippers, motors, gear trains etc.) is strongly affected by various surface phenomena as friction/stiction, micro and nanoscopic wear, surface contamination and environmental effects. Same problems are also met in microrobotic assembly based high resolution micromanipulators and gripping devices which are dedicated to mesoscopic sized components (between a few micrometers and a few millimeters). Current research in this field includes the development of new types of surfaces, which would enable to control separately the various components of friction occurring in dry medium microassembly.
Although the apex of the AFM is commonly used to simulate and study these phenomena, it is generally admitted that the friction level and wear rate obtained with this approach – i.e. on the scale of a single asperity contact – have little to do with the ones obtained in a real microsystem or microgrippers. Indeed, a single asperity can not take into account the mutual interaction coming from all neighboring contacts (so-called real contact area) and, the comprehension of mechanisms that contribute to the overall view of friction is generally insufficient: that is, (i) the scale dependence of friction by varying the loading and the sliding velocity in large scales; (ii) the thermal effects, the physico-chemical interactions and the influence of the environment ; and finally, (iii) the formation of wear debris which usually controls friction and wear within the contact. In addition, the levels of contact pressure in that configuration are often much higher than real MEMS or grippers (several GPa instead of several tens or hundreds MPa) leading to study phenomena which can be completely different than those really occurring in current microsystems.

So, the development of new devices suited for the characterization of multi-asperity tribological properties of surfaces is needed.

Objectives

This PhD position has two main objectives:

- Experimental validation in air and controlled environment of a new tribometer based on the MEMS technology with piezoresistive beams [1]. This latter is an advanced prototype whose development and qualification need to be achieved. This necessary final stage will be completed in close collaboration

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between Minamas (MN2S dep[t]) and Specimen (AS2M dep[t]) teams. Minamas will provide skills, samples and equipments in the field of tribology [2-5]; and Specimen will provide skills and expertise in the field of micro and nanoforce sensors [6-14]. These two teams have used to work together since several years through various research programs (STILµForce ANR project and FIMICAP Regional Project) [6]. The samples displaying triboactive properties are currently studied by the Minamas team [5] and should be suitable for micro/nanorobotics [4].

- Because nanorobotics is usually carried out in vacuum, a new equipment has to be developed in the experimental research environment provided by the new ROBOTEX Equipex located at ENSMM/Besançon (large vacuum chamber equipped with dual-beam FIB/SEM, multiple gas lines and micro/nano manipulators). ROBOTEX is devoted to the study and manipulation within the robotics paradigms of components of intermediate sizes located between the hundred nanometers and a few micrometers. The new equipment to develop is based on the design and the realization of new devices which should make possible: (i) the measurement of the adhesion properties of the surfaces, and (ii) the tribological properties assessment in vacuum. Expected performances should be comprised into the actual gap that exists between AFM (mono-asperity friction characterization) and microtribometers (multi-asperity friction characterization). Stages (i) and (ii) will be conducted in the same experimental set-up, as an *in situ* approach, without getting the samples out of the vacuum reactor. This work will be done under the expertise of AS2M department in the field of mono and multi-DOF micro/nanoforce measurement with piezo resistive beams and magnetic springs [1, 6-14].

Wished skills

Mechanical engineering, signal processing and mechatronics.
The candidate will be internally trained depending on his (her) initial skills.

References

[1] Xin Xu, Joël Agnus, Three dimensional piezoresistive MEMS force sensor for friction measurement, Applied Physics Letters, submitted;
[2] Ph. Stempflé and al (2010), Tribology Int. 43, 1794-1805;
[3] Ph. Stempflé, J. Takadoum (2012), Tribology Int. 48 (2012) 35-43;
[4] Ph. Stempflé and al, (2012), Tribology Int., DOI : 10.1016/j.triboint.2012.05.026;
[5] A. Domatti, Ph. Stempflé, J. Takadoum, Proc. of NORDTRIB 2012, Trondheim (Norway), paper 94;
[6] J. Dejeu and al, Proc. of NORDTRIB 2010, Storforsen, Suede, paper 23, 9 pages, June, 2010;
[7] E. Piat, J. Abadie, S. Oster, Sensors and Actuators: A. Physical, Vol. 179, pp 223-236, June 2012;
[8] J. Abadie and al, Sensors and Actuators : A. Physical, vol. 173, pp 227-237, January 2012;
[9] A. Cherry, E. Piat, J. Abadie, Sensors and Actuators : A. Physical, vol. 169, pp. 27-36, sept. 2011;
[10] A. Cherry, E. Piat, J. Abadie, JESA, vol. 44, n° 6, pp 631-659, 2010;
[11] E. Piat, J. Abadie, S. Oster, Proc. of IEEE ICRA'12, pp. 1416-1421, St. Paul, USA, May 14-18, 2012;
[12] E. Piat, J. Abadie, S. Oster, Proc. of IEEE IROS'11, pp 39-44, San Francisco, USA, Sept. 25-30, 2011;
[13] A. Cherry, J. Abadie, E. Piat, Proc. of IEEE ICRA'07, pp 10-14, Italie, 2007;
[14] A. Cherry, J. Abadie, E. Piat, Proc. of IEEE IROS'07, pp 1118-1123, USA, 2007;

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