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# MICRO/NANOROBOTICS IN TECHNOLOGICAL MICRO/ NANOPROCESSING AND MICRO/NANOSYSTEMS ENGINEERING

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**Abstract:** *Micro/nanorobotics applications make it to expand in several areas. Some of the most important applications are nanopositioning and nanomanipulation. Technologies /micro-nanotechnologies for nanomanipulation include observation, setting in motion, measurement, system's design and manufacture, calibration and control.*
*We are using a Hexapod positioning system, Micro-Movement F-206, for positioning the samples studied with an atomic force microscope. The connection between these two systems is done with a finger device that allows nanopositioning of samples. This system is used for characterizations and determinations of tribological parameters of surfaces containing different materials. We determined roughness surfaces of some femoral heads from hip prostheses realized by steel, CoCrMo, steel coated with TiN; polycrystalline diamond compact surfaces COMPAX 1321; steel–component material of different mechanical parts.*
*Key words: Micro/nanorobotics, micro/ nanopositioning, micro/nanoprocessing, micro/nanosystems engineering*

## 1. INTRODUCTION

On the nano-scale basis, technology has shifted to a more powerful and intelligent control of material structure, suggesting the feasibility of achieving the control of the molecular structure of matter atom by atom.
Nanorobotics deals with the study of nanometer scale robotics and include robots that are nanometer-size and large robots able to manipulate objects with nanometer dimensions. Nanorobotics [1] integrates various disciplines, including nanofabrication processes used to produce nanoactuators, nanosensors and nanometer scale physical modeling. In this field are also included manipulation technologies, like nano-scale assembly of units, biological cells and molecules manipulation and types of robots used to perform these tasks.
Materials science, biotechnology, biomedical sciences, engineering sciences, electronics and mechanical stimulation will benefit from nanorobotics developments [2]. With the ability to position and orient nanoscale objects, nanorobotic manipulation is a promising way to enable the assembly of nanosystems, construction and characterization [3] of micro/ nanoelectromechanical systems (MEMS/ NEMS). Materials characterization is important when we want to determine features of different surfaces that are used in many areas. Tribological parameters help to this type of characterization, mainly for worn surfaces. There are techniques with complex mechanisms that allow to obtain these parameters and to observe all the surface characteristics.

## 2. MANIPULATION METHODS

The most common ways to achieve nanometer scale setting in motion are the electrostatic, electromagnetic and piezoelectric. For nanorobotics manipulation the actuators, generating large movements and forces, are the most suitable for such applications.

Electrostatic charge is based on the accumulation of free electrons in a material, which can exert an attractive force on opposite charged objects or a repulsive force on similar charged objects. Very low power consumption associated with electrostatic devices determines moving highly efficient implementation.
Electromagnetic fields appear by the movement of electric current through a conductive material. Attractive or repulsive forces are generated adjacent to the conductor and proportional to current flow. Focusing and accumulating these forces, the movement will be created.
Piezoelectric movement appears after dimensional changes generated in certain crystalline materials subjected to an electric field or an electrical charge. In this way structures can be achieved, which collect and focus the force of dimensional changes and uses them to create movement. At the micro-scale, piezoelectric materials were used in linear transport devices and most nano-manipulators use piezoelectric actuators.
Thermal movement produced by thermal expansion amplification refers to the tendency of matter to change in volume in response to a change in temperature.

## 3. NANOROBOTIC SYSTEMS FOR NANOMANIPULATION

Technologies for nanomanipulation [4] include observation, setting in motion, measurement, system's design and manufacture, calibration and control, the results dissemination and man-machine interface. The basic requirements for a nanorobotic 3D system for nano-manipulation include nanometric scale positioning resolution, a large workspace, sufficient freedom degrees and orientation's control of multiple effectors for complex operations.
Nanomanipulation was made possible by scanning tunneling microscopy (STM), atomic force microscopy (AFM) and other types of microscopes appearance to scan the sample [5]. Nanorobotic manipulators (NRMs) have 3D positioning capacity, orientation's control and systems employed in real-time observation that can be integrated with microscopes to scan the sample.
STM can be applied to particles with the size of atoms. A standard STM is not suitable for complex manipulation and cannot be used in 3D space because of its limitation in 2D positioning.
AFM manipulation involves the movement of an object by tapping it with a tip. A typical manipulation occurs as follows: the image of a particle in non-contact mode, then oscillations remove and the sweep of the tip over the particle that is in contact with the surface. The mechanical pushing can exert more powerful forces on objects and so, it can be applied to manipulate larger objects. 1D and 3D objects can be manipulated on a 2D substrate.
A nanorobotic manipulation system with 16 degrees of freedom (DOFs) is shown in Fig. 1a, which can be equipped with three or four AFM tips as effectors both for manipulation and measurement.

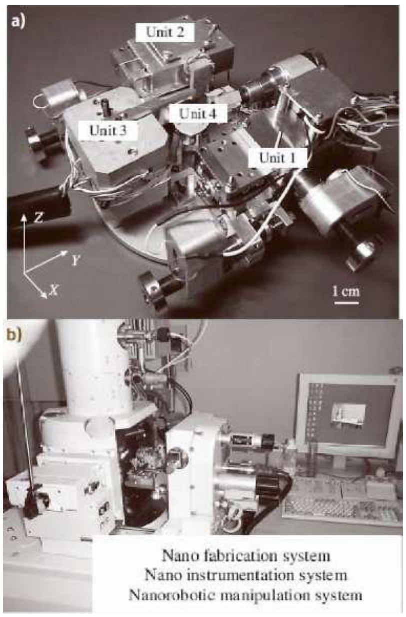



Fig. 1. Nanorobotic system. (a) Nano-robotic manipulators. (b) System set-up.

The main functions of this nanorobotic manipulation system are nano-manipulation, nanoinstrumentation, nanofabrication and nanoassembly. Measurements of four semiconductor samples are probably the most complex manipulation that can perform this system because it is necessary to stimulate four independent samples by four manipulators. If all four samples are used together, many and various applications are possible for manipulators.

A nanolaboratory shown in Fig. 1b integrates a nanorobotic system for nanomanipulation with an analytical system and a nanofabrication system. It is a complex system, taking into account that it can be applied for nanomaterials manipulation, nanogroups manufacturing, nanodevices assembling and in situ properties analysis of such materials, groups and devices.

## 4. TECHNIQUES AND MECHATRONIC SYSTEMS USED FOR CHARACTERIZATION OF MATERIALS SURFACE

Wear processes occurring inside different systems are often impossible to see with the naked eye. A methodology of ascending degrees of resolution was established using macroscopic (resolution millimetres), microscopic (resolution microns) and nanoscale (resolution nanometers) measurements.

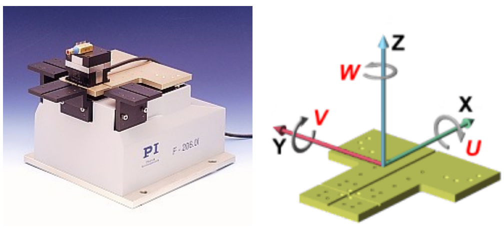
Characterization of worn surfaces and determination of its tribological parameters can be achieved by noncontact surface measurements using atomic force microscope, confocal microscope, scanning interferometer or triangular laser.

At INCDMTM, characterizations and determinations of tribological parameters for surfaces containing different materials are realized using an atomic force microscope (Microscope Probe NTEGRA - Fig 2) working in the noncontact mode. Working principle of AFM is to measure the interaction force between tip and sample surface using special measuring heads, made of a cantilever with a pointed end.

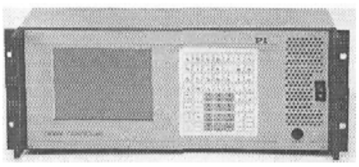

Fig. 2. Atomic Force Microscope NTEGRA Probe NanoLaboratory: 1 – base unit; 2 – measuring head; 3 – vibration isolation system; 4 – optical viewing system.

The samples are positioned on the base unit of AFM using a robotic nanomanipulator that has more DOFs including rotation for control of orientation and thus, can be used to manipulate 0D objects (spherically symmetric) to 3D objects in space [6].

A Hexapod positioning system for Micro-Movement, F-206 [7], being produced by Physics Instruments (PI) GmbH & Co KG, Karlsruhe, Germany, is used in this experiment and is integrated at INCDMTM, within MEMS/NEMS laboratory. This 6-axis positioning system consists of an attachment position system (Fig. 3a) and a control unit (Fig. 3b).




(a)




(b)

Fig. 3. F-206 alignment and positioning system with six axes: (a) hexapod positioning system – all commands and operations are using (X, Y, Z and U, V, W) coordinates. Travel range: X = -8 to +5.7 mm, Y = ±5.7 mm, Z = ±6.7 mm, U = ±5.7°, V = ±6.6°, W = ±5.5°; (b) control unit.

A keyboard and a monitor for the control unit may be used to control F-206 system directly or, typically, the control unit can be controlled by a PC. System's mechanics uses a parallel - cinematic positioning system, containing 6 linear actuators with screw actuators and optical encryption systems. The system provides 6 DOFs and a minimal increase of movement of 0.1 µm. Workspace boundaries are not parallel to the axes, but it cannot overcome a rectangular solid which is given by the limits of movement X, Y and Z. The control unit is equipped with integrated software to define a pivot point anywhere inside or outside workspace of F-206 system. Rotation around this pivot point may be ordered for any combination of the 3 rotation axes.

All orders for positioning "F-206 platform" are given in orthogonal coordinates and converted by command system in F-206 specific actuator positions and speeds before making the action.

The connection between NTEGRA Atomic Force Microscope and the Hexapod positioning system for Micro-Movement F-206 is done with a finger device (gripper) that allows nanopositioning of samples used. A scheme of the obtained complex system used to characterize and analyze the studied surfaces is presented in Fig. 4.

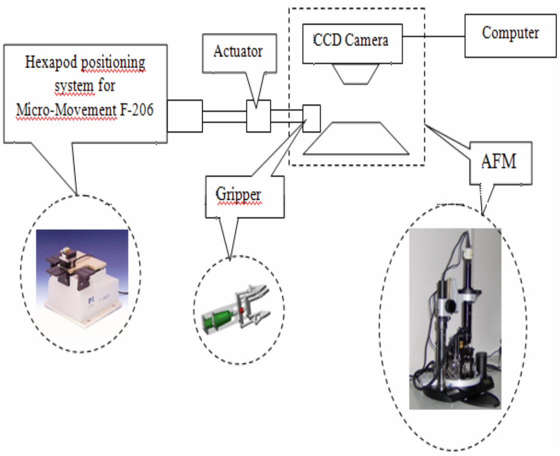



Fig. 4. Complex mechatronic system made up of NTEGRA Atomic Force Microscope and F-206 alignment and positioning system with six axes.

## 5. EXPERIMENTAL RESULTS CONCERNING TRIBOLOGICAL CHARACTERIZATION OF DIFFERENT MATERIALS SURFACES

In our institute were carried out characterizations and determinations of tribological parameters (like surface roughness) of different surfaces: areas of the femoral heads of hip prostheses CoCrMo (Fig. 5), femoral heads of hip prostheses TiN (Fig. 6), femoral heads of hip prostheses Ti6Al4V (Fig. 7), polycrystalline compact diamond COMPAX 1321, steel – component material of different mechanical parts.

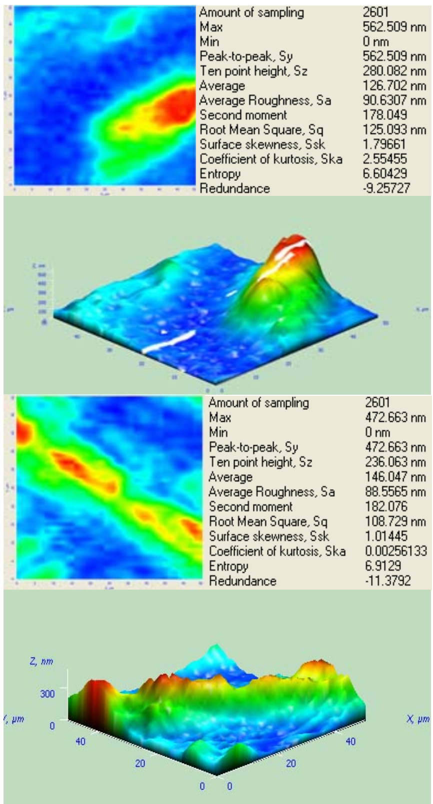



Fig. 5. Tribological characterization of CoCrMo surfaces using NTEGRA AFM

Femoral heads surfaces and component parts made of steel, titanium alloys or CoCrMo alloys, generally, deteriorate due to the pressures produced by mechanical movements of the systems it is part of.

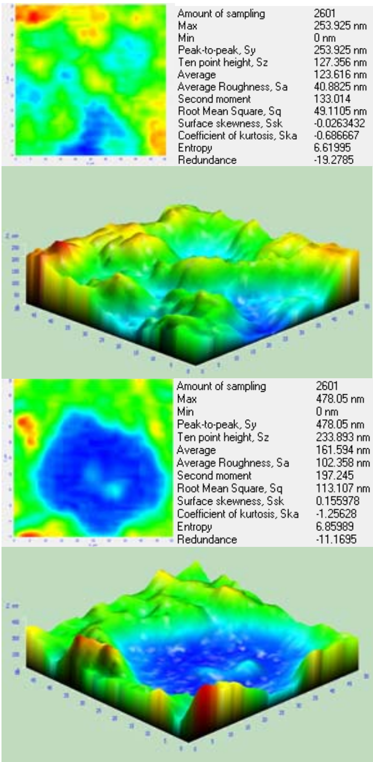


Fig. 6. Tribological characterization of TiN surfaces using NTEGRA AFM

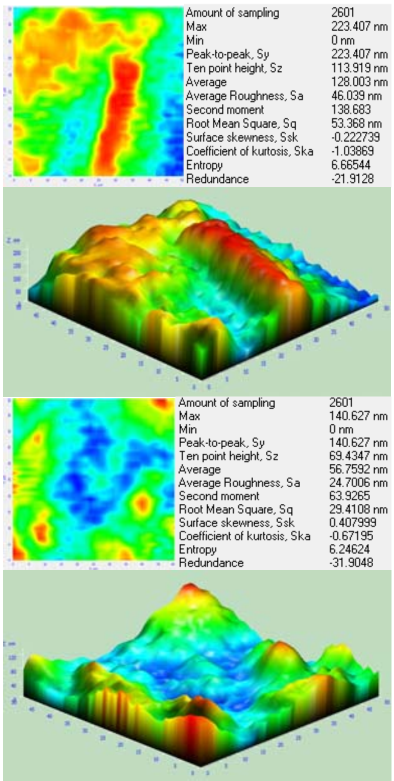


Fig. 7. Tribological characterization of Ti6Al4V surfaces using NTEGRA AFM

As it is shown in the examples presented, roughness has different values (in different parts of the same femoral head) depending on the movements of the body that uses the prostheses.

Besides the hip prostheses surfaces characterization, were also characterized several polycrystalline compact diamond COMPAX 1321 surfaces. This material can be used as an active part of a lathe tool for processing metallic/non-metallic materials. Tribological parameters obtained can be seen in Fig. 8, together with the 3D image of the worn surface.

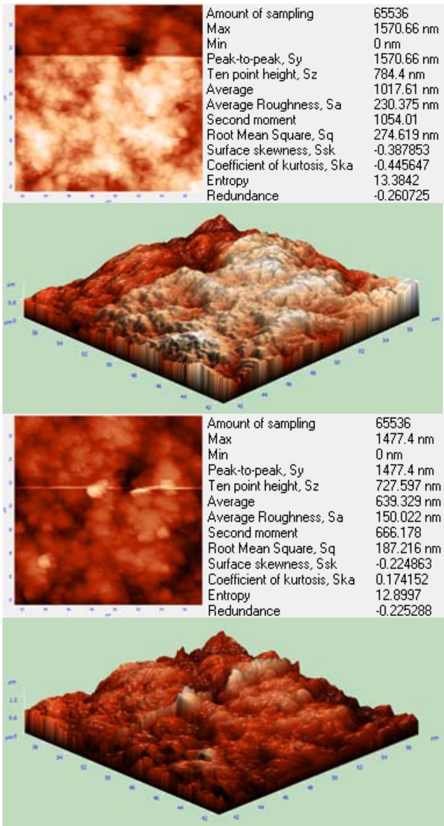


Fig. 8. Tribological characterization of polycrystalline compact diamond COMPAX 1321 surfaces using NTEGRA AFM

## 6. CONCLUSION

In order to obtain a clear characterization of realized parts surfaces or the coatings from the femoral head of a hip prosthesis the study of its topography and roughness determination are useful. Such a study can be made by different techniques and different systems. AFM was used because its images display high quality and dense nanocrystalline structure of prepared thin films. NTEGRA Probe Microscope has been connected with a Hexapod positioning system for Micro-Movement F-206 in order to obtain a complex positioning of the sample, followed by surface characterization and determination of few tribological parameters.

INCDMTM Bucharest, Romania, by its MEMS/NEMS Laboratory, will develop in the future, micro/nanorobotic systems/ micro/nanosystems for micro/ nano-manipulation and micro/ nanopositioning, micro/ nanotechnological micro/ nano-platforms for European modernization and qualifications of micro/ nanoindustries and micro/ nanoengineering.

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