

Atomic Force Microscopy in controlled environment: a powerful tool for original experiments on hybrid systems, biomaterials, and biocomposites.

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There is a growing research interest on hybrid systems, biomaterials, and biocomposites because of their industrial application demands. Owing unique properties of these materials make more attractive in electronic, medical and transport applications.

Whatever the application field, a constant need of miniaturization, performance, structure lightening necessitates working and exploring the material properties at nanoscale. To do this, one of the most powerful tool is Atomic Force Microscopy (AFM). By using AFM nanoscale tips, which interact with matter due to attractive and repulsive forces, numerous properties can be studied systematically. Due to its strong impact on properties and behaviour, temperature is considered as a key parameter. Indeed, its variations induce a significant change in material behaviour which can be positive (adhesion for example) or negative (electrical change). Consists of tip, micro-lever, photodetector, laser and control loop, the AFM can be used in different modes *i.e.* tapping, contact, non-contact, and PeakForce QNM. Consequently, a wide selection of measurements can be made under controlled environment (humidity, liquids, temperature, etc.), and with different purposes such as topography, electrical measurements, force measurements, PeakForce-QNM.

To illustrate the contribution of the technics, different applications are presented. In the first part, a combination of AFM and RX reflectivity is used to understand the structure and interfaces of hybrid nanofilms (Polystyren/Gold) at different temperatures (-20°C to 220°C). In this way, AFM has been used to highlight different properties which are not possible to study by other technics such as electrical behaviour, adhesion and surface characterization with a new method (IDF). In addition, complementary experiments have been performed using X-ray reflectivity and Raman Spectroscopy.

In the second part, different force mapping has been investigated with different environmental conditions. It is well known that the ceramic materials are widely used as implants. Currently, it is possible to develop customized implants by 3D printing technology. In order to study the bone reconstruction of ceramic materials in non-osseous site, biomolecules are used to induce bone regeneration. Adhesion mappings were made using functionalised tips (fibronectin). Moreover, by studying interactions between tips and ceramics, it's possible to find an optimal ceramics chemical composition and biomolecules in the implant materials. These experiments were carried out in air and in liquid at 37°C.

Finally, flax fibres based biocomposites were used in transport applications because of their interesting specific mechanical properties. These biocomposites are processed at elevated temperature which can affect the anatomy of flax fibers. Therefore, the PeakForce QNM tool has been used to examine the impact of flax fibers composite processing temperature on flax cell walls structure and stiffness from room temperature to 250°C. To validate the method, comparison has been established with nanoindentation experiments.