Nanomechanical characterization of soft materials and nanocomposites by atomic force microscopy

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INTRODUCTION: Atomic force microscopy (AFM) has been extensively used as a platform to develop techniques for the mechanical characterization of materials at the nanoscale. Through them the mechanical properties of a wide range of samples, from stiff materials to compliant polymers, biomaterials and biological samples, can be qualitatively and/or quantitatively measured in a single point or mapped on a selected area on the sample surface. Moreover, nanomechanical imaging may be employed to image stiff nanomaterials included in soft matrices. In this work, we review some of these techniques. As examples, AFM quasi-static indentation (I-AFM) has been used for year to study the mechanical properties of soft matter [1]. More recently, such properties have been mapped by contact resonance AFM (CR-AFM) and other ultrasound based AFM techniques [2]. Such techniques, in particular those based on nonlinear effects, have been demonstrated to enable the detection of nanoparticles buried in polymers [2,3] or internalized in biological structures [2]. Explicitly developed for soft matter, torsional harmonics AFM (TH-AFM) has been used to measure and map the elastic modulus of polymers and biological samples [1,2]. We report here also some results on polymeric nanocomposites and biomaterials and biological samples.

METHODS: I-AFM and CR-AFM have been performed using a Solver AFM apparatus (NT-MDT, Russia) equipped with standard Si cantilevers. TH-AFM has been performed using an Icon AFM apparatus (Bruker Inc.), equipped with T-shaped cantilevers.

RESULTS & DISCUSSION: I-AFM, CR-AFM and TH-AFM have been used to characterize the indentation modulus of a number of different polymer-nanodiamond (ND) composites. As an example, Fig. 1a and 1b show the topography and the elastic modulus map, respectively, obtained through TH-AFM, of a fibre of polyaniline (PANI) doped with ND, surrounded by nanofibrils, on a Si substrate. Similar characterization has been performed on poly-aminopropyltriethoxysilane doped with ND, which revealed the stiffening of the polymer induced by the ND. Results retrieved through different techniques have been compared, showing their substantial agreement. Increase of the elastic modulus of fluorocarbon ultrathin films has been studied as a function of exposition time to methanol plasma, which increases also the biocompatibility and proliferation of endothelial cells. Finally, nanomechanical characterization of some biological samples (collagen fibres and bacteria) has been reported.

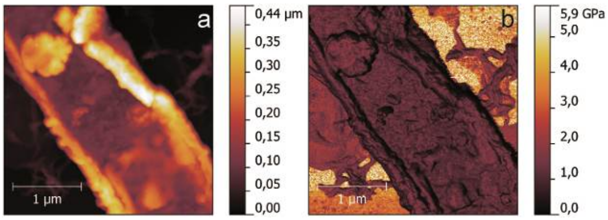

Fig. 1: Topography (a) and indentation modulus map (b) of a PANI-ND fibre and nanofibrils.

CONCLUSIONS: AFM has been described as a powerful platform to develop techniques for the nanomechanical characterization of soft matter. Comparison among results obtained on some polymers through different techniques demonstrates the reliability of the techniques. While polymers represent well established samples to be characterized though these techniques, efforts are still required to the complete extension of our techniques to biological materials.

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