AFM-based methods for Elastic Measurements

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Due to its unique capability to probe samples with high spatial resolution using a nanometer-sized tip which is 'in touch' with the investigated surface [1], atomic force microscopy (AFM) has been used as a versatile platform to develop advanced methods for the characterization different physical properties of materials at the nanoscale. Among them, several AFM-based techniques have been proposed for the quantitative nanomechanical characterization of samples. Indeed, the AFM tip is capable to exert a controlled force on an area of the surface with nanometer dimensions as a result of the elastic force produced by the cantilever deflection. Such a physical interaction, which can be continuous (i.e., in contact mode) or limited in time and periodical (i.e., in intermittent contact mode), can be used to locally probe the mechanical response of the material in order to quantitatively characterize its mechanical properties. Depending on the approach used to probe the mechanical response of the sample, several different AFM-based nanomechanical techniques have been developed, e.g., those based on the acquisition of force-indentation curves using the AFM tip like as an indenter or those based on the combination of AFM with ultrasound-based nondestructive testing. Here we give an overview of some of these techniques, emphasizing advantages and disadvantages with particular reference to the range of elastic moduli of the sample which can be analyzed.

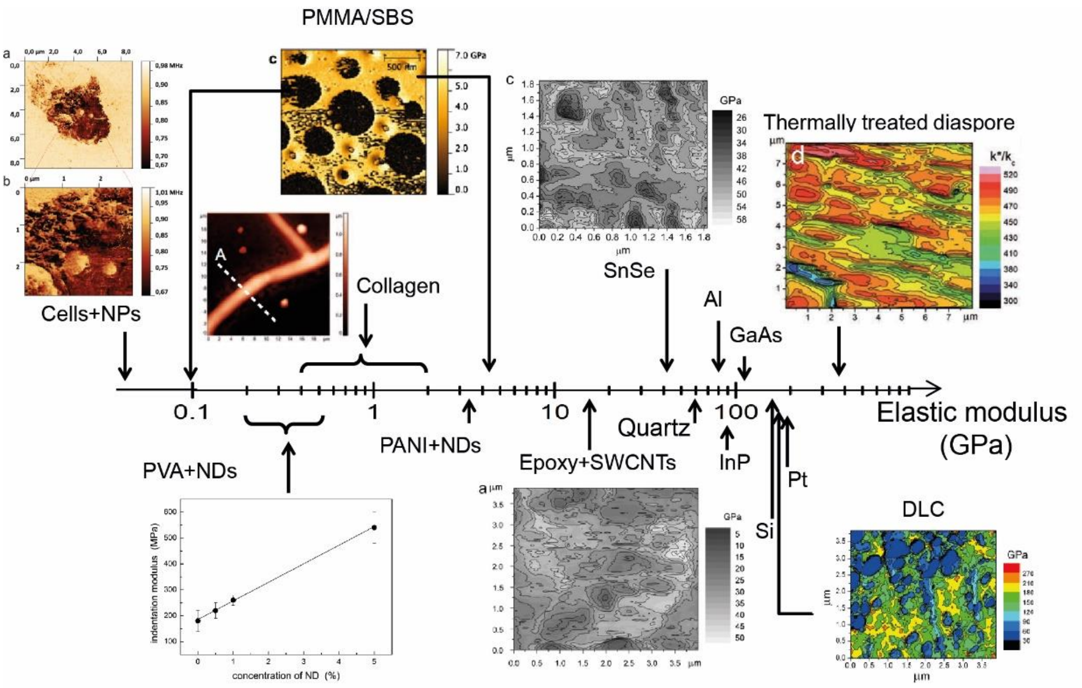

Figure 1. Example of different samples which can be characterized using AFM-based techniques with reference to their elastic modulus.

Using the AFM tip as an indenter, AFM-based quasi-static nanoindentation allows one to evaluate indentation modulus and hardness of materials with nanometer lateral resolution, although the accuracy of the method is limited by the variability of the tip shape, which therefore should be carefully calibrated [2]. Also, the need for a measurable static indentation of the sample makes AFM-based nanoindentation accurate only on relatively compliant materials, e.g., polymers or biological samples.

Among the family of AFM-based techniques which can be used to measure nanomechanical properties of materials combing the AFM-based approach with the use of ultrasonic waves exciting the analyzed systems, contact resonance AFM (CR-AFM) is undoubtedly one of the most versatile methods as it enables the analysis of materials in a broad range of values of elastic moduli as sketched in Fig. 1 [3]. Also, recent advancements in CR-AFM have been demonstrated capable to characterize not only elastic materials, but also viscoelatistic, allowing the quantitative characterization of storage and loss moduli as well as loss tangent also at variable temperature [4]. Nonetheless, being based on contact mode, the use of CR-AFM on soft materials may be limited and thus different approaches based on intermitted contact have been developed.

The availability of other methods, either based on AFM contact mode or intermittent contact mode, allows one to have a set of techniques to be synergistically used on the advanced mechanical characterization at the nanometer scale.

References

[1] G. Binnig and H. Rohrer, “In touch with atoms”, Rev. Mod. Phys., vol. 71, S324-S330, 1999.
[2] D. Passeri, A. Bettucci, A. Biagioni, M. Rossi, A. Alippi, E. Tamburri, M. Lucci, I. Davoli, and S. Berezina, “Indentation modulus and hardness of viscoelastic thin films by atomic force microscopy: A case study”, Ultramicroscopy, vol. 109, 1417-1427, 2009.
[3] D. Passeri, A. Bettucci, and M. Rossi, “Acoustics and atomic force microscopy for the mechanical characterization of thin films”, Anal. Bioanal. Chem., vol. 396, 2769-2783, 2010.
[4] M. Natali, D. Passeri, M. Reggente, E. Tamburri, M.L. Terranova, and M. Rossi, “Contact resonance atomic force microscopy for viscoelastic characterization of polymer-based nanocomposites at variable temperature”, AIP Conf. Proc. Vol. 1749, p. 020008, 2016.