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Surface and Subsurface Physical and Chemical Characterization of Materials at the Nanoscale

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In modern microscopy, spatial and spectral resolutions are of great importance in tackling questions related to material properties. The emergence of the atomic force microscopy (AFM), which surpasses what can be achieved optically due to the inherent diffraction limit, has opened numerous opportunities for investigating surfaces. However, a contemporary challenge in nanoscience is the non-destructive characterization of materials. In addition, techniques providing both physical and chemical information are needed to reach a comprehensive understanding of the composition and behavior of complex systems.

In order to tackle the subsurface and spectral imaging, here we propose to make use of the nonlinear interaction forces between the atoms of an AFM probe tip and those of a given sample surface. Such forces are known to contain a short range repulsive component and a long range van der Waals attractive contribution. This interfacial force can give rise to a multiple-order nanomechanical coupling between the probe and the sample, offering tremendous potential for obtaining a host of material characteristics. By applying a multi-harmonic mechanical forcing to the probe and another multi-harmonic forcing to the sample, we obtain, via frequency mixing a series of new operational modes. By varying the nature of the excitations, using elastic or photonic coupling, it is possible to obtain physical and chemical signature of a heterogeneous medium with nanoscale resolution. The technique, termed mode synthesizing atomic force microscopy (MSAFM) is therefore described as a generalized multifrequency AFM.

We highlight the versatility of MSAFM and its potential to contribute to important problems in material sciences, toxicology and energy research, by presenting three specific studies: 1- imaging buried nanofabricated structures; 2- investigating the presence and distribution of embedded nanoparticles in a cell; and 3- characterizing the complex structures of plant cells.