

Analysis of mechanical heterodyning principle in Scanned Force Microscopy (SFM) – spatial resolution, time sensitivity and contrast mechanisms.

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First reports on merging of scanning force microscopy (SFM) and high frequency (HF) ultrasonic methods [1, 2] have opened a possibility for exploration of short time scale physical phenomena with nanoscale spatial resolution. Such approaches can be clustered into two groups based on the dynamic nature of the tip-surface contact. In the first group [eg. 2], the tip and the surface are always in contact and HF ultrasonic vibration is modulating the tip-surface force around equilibrium value. Due to the near-linear nature of such a system, an application of harmonic oscillatory force results in the response at same frequencies, as if each stimulus is acting independently.

The second group is characterized by the tip-surface contact that is broken intermittently during part of the ultrasonic period oscillation (eg. Ultrasonic Force Microscopy, or UFM [1]). It is such HF modulation that leads to the variety of non-linear physical phenomena that can be successfully exploited in the SFM. An additional (but very important) benefit of UFM like approach is the elimination of the average lateral force between tip and surface, that leads to gentler probing of materials and minimal tip damage. Another feature of this non-linear behavior is a possibility to convert a HF force interaction (on microsecond to sub-nanosecond time scale), to the low frequency (kHz) range, where such forces are easily detectable. Such nonlinear mixing via heterodyne principle is well known (eg. in wireless communication and HF network analyzers). In SFM we named such approach a Heterodyne Force Microscopy, or HFM [3, Fig. 1].

In this paper we are reporting observation in HFM elastic moduli and viscoelastic relaxation of biological materials including abalone shell (a natural nano-composite of inorganic aragonite and thin binding protein layers [Fig. 2]). We are also discussing performance of HFM for detection of non-mechanical physical phenomena and limits of its a) force, b) time and c) depth sensitivity. Finally, we are discussing potential of HFM for studies of time-dependent phenomena in shear polarized and thermal phonons, particularly a combination of HFM with the scanning thermal microscopy by Hammish and Pollock [6].

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