Accurate Nano-Mechanical and Nano-Electromechanical Measurements using Interferometric AFM

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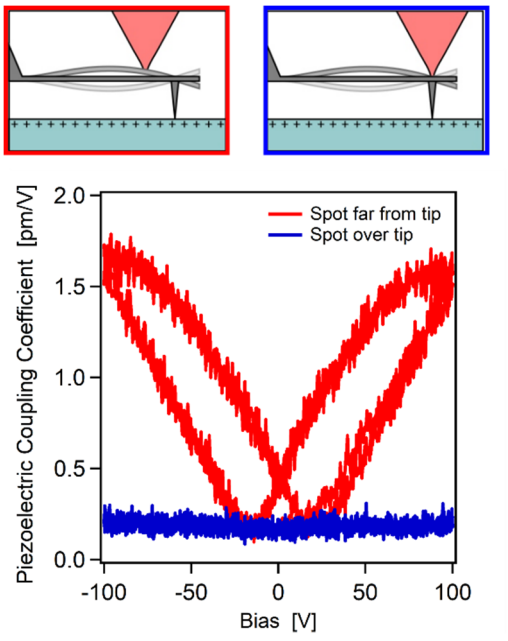
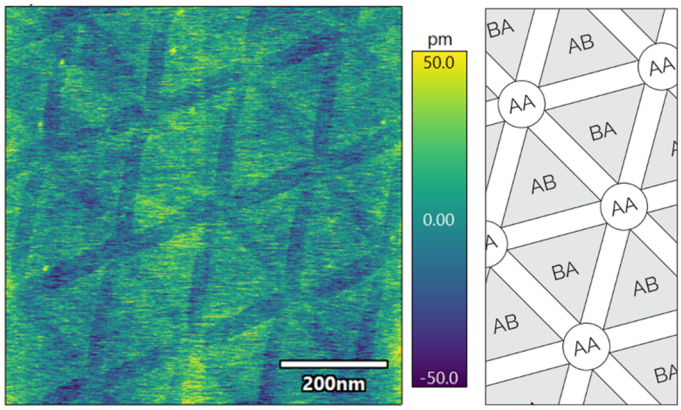
Most of ambient and liquid AFM utilized optical beam deflection (OBD) as detection method of tip-sample interaction. OBD signal is related to change of cantilever's angle. However, quantifying tip displacement is required to evaluate mechanical properties of samples. In many previous studies, OBD signal is converted to tip displacement based on calibration of deflection sensitivity. However, this conversion is not straightforward but affected by friction and cantilever dynamics. Here we have developed a new interferometer-based detection, called quadrature phase difference interferometer (QPDI). QPDI measures pure vertical tip displacement directly, and its accuracy is based on wavelength of light. Moreover, the noise level of QPDI is remarkably low - less than 10 fm/Hz$^{1/2}$. We showed QPDI minimized artifacts in Piezoresponse Force Microscopy (PFM) caused by electrostatic force and cross-talking with in-plane component of sample response. With QPDI low noise performance, we succeeded in visualizing Moiré pattern of twisted 2D materials in topography by contact mode imaging. We showed more accurate mechanical mapping by force curves with lower forces and shorter acquisition time. QPDI is expected to become a standard component for next generation AFM.



(a) QPDI SS-PFM on Soda Lime Glass



(b) Moiré Pattern on twisted bilayer graphene by contact mode height image

Figure 1. (a) PFM amplitude hysteresis curve measured on tip (blue) and away from tip (red) on non-ferroelectric glass. Cantilever vibrates by electrostatic force and causes hysteresis (red), but it is avoided to detect in tip displacement measurement (blue). (b) Contact mode height image on twisted bilayer graphene, showing Moiré pattern.