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Joseph F. Keithley Award: Force microscopy with subatomic spatial resolution

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For a long time, atomic force microscopy has been inferior to the scanning tunneling microscope (STM) in its spatial resolution, partially because measurements of small forces are more challenging than measurements of small currents. With the introduction of frequency modulation force microscopy, the static deflection measurement of a cantilever under a tip-sample force was replaced by a frequency measurement of an oscillating cantilever induced by an average force gradient. Atomic resolution of the challenging silicon reconstruction by frequency modulation atomic force microscopy has been demonstrated in 1995 using a silicon cantilever with a stiffness of k =17 N/m and an oscillation amplitude of A =34 nm. In 1996, a quartz cantilever ("qPlus sensor"), originally built from a quartz tuning fork from a wristwatch, has been proposed. At k =1800 N/m, this quartz sensor is 100 times stiffer than the original Si cantilever, allowing stable oscillation amplitudes down to fractions of an atomic diameter. It has a high Q factor, simple piezoelectric readout, little frequency variation with temperature and allows to simply mount metal tips as used in STM. The demonstration of high spatial resolution, the detection of very small forces, the capability to perform simultaneous STM and AFM as well as the ease of use of the qPlus sensor has led to its adaptation in leading scanning probe microscopy laboratories worldwide as well as in a growing number of commercial scanning probe instruments.