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Scanning Probe Microscopy at mK Temperatures *

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Scanning probe microscopy has made significant advances with a wealth of new physics emerging as cryogenic instruments have been developed in the last decade allowing high resolution spectroscopic studies with spatial atomic resolution [1]. Most low temperature SPM instruments today operate at 4 K using liquid ^{4}He, with a few exceptions [2]. In this talk, we describe the next generation of ultra low temperature scanning probe microscope (SPM) with high magnetic field (15 T) capability operating at 10 mK using the circulation of a ^{3}He-^{4}He mixture in a dilution refrigerator (DR). With this system operating at 10 mK, we can extend the capability of scanning tunneling spectroscopy to higher energy resolution ($\approx$3 μeV) for a range of applications in nanoscale systems. To achieve the design goal of mK operation for SPM applications we designed and constructed an ultra-high vacuum (UHV) SPM-compatible DR, an ultra-low temperature compatible SPM module, and extensive vibration isolation and RF shielding components. The DR was designed and constructed with features specific for UHV SPM applications, such as a Joule-Thomson (JT) condenser for lower noise operation. Noise measurements of the tunneling current show virtually no circulation-induced noise using the JT condenser, in contrast to noisy operation with a 1K pot. The custom-designed SPM module, with a three-axis position stage, is made from coin silver and ceramics for rigidity and thermal conduction in the mK regime. We also developed and constructed a low temperature current pre-amplifier, operating on the still at 650 mK, to circumvent problems due to long cable capacitances. Extensive noise measurements and first scanning measurements on graphene samples will be described. *In collaboration with Alexander F. Otte, Young Kuk, Phillip N. First, Walt A. de Heer, and Joseph A. Stroscio [1] D. L. Miller, *et al.*, Science **324**, 924 (2009) [2] A. J. Heinrich, *et al.*, Science **306**, 466 (2004)