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Scanning probe microscopy with single-molecule sensors and transducers: New ways to visualize molecules and their properties

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As nanoscience progresses, it becomes ever more important to "see" molecules on surfaces with submolecular resolution. But it is not just the structure of a molecule that is of interest. It is of equal importance to visualize as many of its properties as possible on a submolecular scale. Scanning probe microscopy with single-molecule sensors and transducers offers a framework to approach this challenge [1]. If the junction of a scanning tunneling microscope (STM) is functionalized with a nanoscale particle, images can be obtained that reveal the geometric structure the sample [2]. The particle (H2, CO, Xe) acts as a force sensor, sensing forces and transducing them into a conductance signal [3,4] that can be calibrated [5]. Indications of intermolecular bonding can also be seen [6,7]. Even the local curvature of the potential can be measured [8]. More recently, we introduced scanning quantum dot microscopy (SQDM). It images electrostatic potentials with sub-nm and sub-meV resolution [9,10]. An aromatic molecule is attached to the tip of an AFM. Single electron charging events of this molecular quantum dot are detected in the dynamic response of the AFM. SQDM, an example of the sensor/transducer approach, can measure electrostatic fields of neutral atoms or molecules as far as 7 nm away from the surface, providing quantitative 3D imaging of electric fields of a wide variety of nanostructures. [1] Temirov & Tautz, in: Noncontact Atomic Force Microscopy Volume 3, Eds. Morita et al. Springer 2015 [2] New Journal of Physics 2008, 10, 053012 [3] PRL 2010, 105, 086103 [4] PRB 2014, 90, 085421 [5] PRB 2013, 87, 081408(R) [6] JACS 2010, 132, 11864 [7] JACS 2011, 133, 16847 [8] PRL 2014, 113, 226101 [9] PRL 2015, 115, 026101 [10] Japanese Journal of Applied Physics 2016, 55, 08NA04