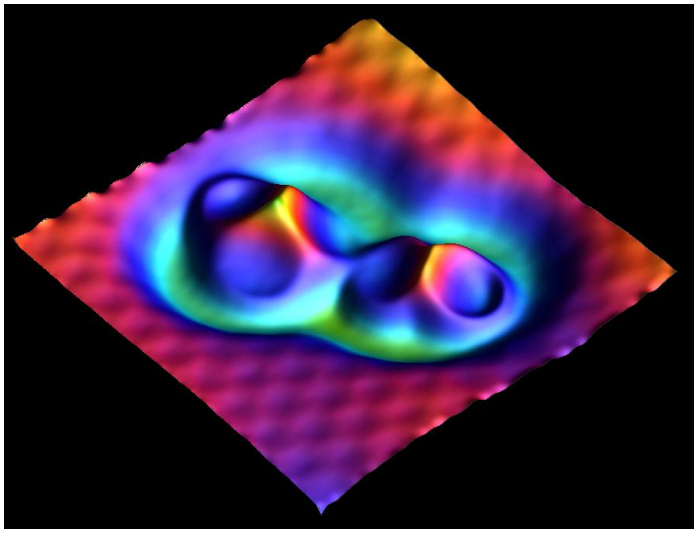
New vistas for nanoscience opened by atomic force microscopy

Franz J. Giessibl
Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany

Atomic force microscopy (AFM) and scanning tunneling microscopy (STM) image surfaces with atomic resolution and enable local spectroscopies such as of current versus voltage and forces versus distance. In the past, STM and AFM used to be separate techniques that required their own instrumentation. The introduction of the qPlus force sensor [1] enabled combined STM and AFM capability, allowing highly precise imaging and spectroscopy functions and measuring the forces that act during atomic manipulation [2]. While STM had better spatial resolution than AFM in the past, the situation is reversed now with modern AFM [3]. Angular dependencies of chemical bonding forces have been observed before for Si tips interacting with Si surfaces [4], W tips interacting with graphite [5] and similarities exist between metal tips interacting with CO molecules on Cu and Si adatoms [6]. In the latter two cases, light atoms such as carbon or oxygen interacted with much heavier and much larger metal atoms. Gross et al. established that CO is an excellent probe for organic molecules. For example, pentacene can be imaged at excellent resolution with CO terminated tips [7], although the softness of CO on tips can lead to image distortions [8,9]. Tips made of permanent magnets such as CoSm allow to resolve the spin order in the antiferromagnetic insulator nickel oxide [10]. Complex surface terminations of the topological insulator $TlBiSe_2$ have been determined by AFM [11]. The stiff cantilever/small amplitude technique used here also allows true atomic resolution in ambient conditions [12], and small iron clusters on Cu (111) are resolved by force microscopy [13]. Very recently, AFM has provided important insights into inelastic tunneling spectroscopy [14]. In summary, we see many exciting avenues in nanoscience research that open up with combined STM and AFM.



AFM image of a Fe trimer next to a Fe dimer on Cu(111) [13].

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