A Low Temperature Scanning Tunneling Microscopy System For

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JIMMY ADRIENNE

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temperature Scanning TunnelingThe authors present the design and first results of a low-temperature, ultrahigh vacuum scanning probe microscope enabling atomic resolution imaging in both scanning tunneling microscopy (STM) and noncontact atomic force microscopy (NC-AFM) modes. A tuning-fork-based sensor provides flexibility in selecting probe tip materials, which can be either metallic or nonmetallic. When choosing a conducting tip and sample, simultaneous STM/NC-AFM data acquisition is possible. Noticeable characteristics that distinguish this setup from similar systems providing simultaneous STM/NC-AFM capabilities are its combination of relative compactness (on-top bath cryostat needs no pit), in situ exchange of tip and sample at low temperatures, short turnaround times, modest helium consumption, and unrestricted access from dedicated flanges. The latter permits not only the optical surveillance of the tip during approach but also the direct deposition of molecules or atoms on either tip or sample while they remain cold. Atomic corrugations as low as 1 pm could

successfully be resolved. In addition, lateral drifts rates of below 15 pm/h allow long-term data acquisition series and the recording of site-specific spectroscopy maps. Results obtained on Cu(111) and graphite illustrate the microscope's performance.Low Temperature Scanning Tunneling Microscopy Studies of Surfaces and MoleculesNanotechnology is described as an emerging science discipline that is expected to have a greater impact on life as we know it than any innovation since the industrial revolution. Superior, cheaper, stronger and more efficient products are predicted to change the way we live, use technology and conduct research. This dissertation focuses on a remarkable instrument, the low temperature scanning tunneling microscope (LT-STM), which is a powerful tool that has played a significant role in revolutionizing the fields of nanoscience and nanotechnology. The work in this dissertation is divided into three sections. First, the fundamental principles of nanoscience and the history of microscopy are introduced. The second part provides a thorough study of Bardeen's formula and its application

in STM. The third part describes experimental investigations involving the physicochemical properties of matter at the nanoscale conducted by means of LT-STM. Studies begin with bare substrate surfaces and successively build in complexity as small molecules, solvents, nanoclusters and large organic molecules are examined on surfaces. Experiments show that carbon monoxide exhibits chemical contrast, while oxygen shows a lack thereof. Solvents are demonstrated to weaken surface bonds and induce surface atom mass transport and the tip is shown to assist the diffusion. Manganese nanoclusters are shown to generate a localized electronic state on graphite by either an electronic or magnetic perturbation. The aromatic molecule, decacyclene (DC) is shown to exhibit both bias-dependent and tip-dependent contrast reversal. In addition, intermolecular interactions are found to compete with the surface-to-molecule interactions as dimers are observed on the surface. Two geometric orientations of the dimers are proposed to explain dimer characteristics and their relation to substrate-dependent properties. Lastly, DC molecules are

examined at coverages in excess of a monolayer and shown to form ordered domains of the boat-shape conformation. This dissertation emphasizes the local modifications of electronic structures upon physisorption and the interplay between surface-to-molecule and molecule-to-molecule interactions, which demonstrate the various complexities occurring at the nanoscale.Design and Construction of a Low Temperature Scanning Tunneling Microscope for Studying High Temperature SuperconductivityLow Temperature Scanning Tunneling Microscope for Single Atom ManipulationDevelopment of a New Low Temperature Scanning Tunneling Microscope to Study Mass Selected Cluster DepositionLow Temperature Scanning Tunneling Spectroscopy of Proximity Effect Junctions Formed on the Layered Superconductors NbSe2 and Bi2Sr2Ca1Cu2O8Low Temperature Scanning Tunneling Microscopy and Spectroscopy in Ultra-high-vacuum and High Magnetic FieldsLow Temperature Scanning Tunneling Microscopy and SpectroscopyA Study on Charge Density Waves and Vortex DynamicsCons

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SubstratesElectron TunnelingInelastic Electron Tunneling Spectroscopy and Low Temperature Scanning TunnelingLow Temperature Scanning Tunneling Microscope Study of Metallic Thin Films and Nanostructures on the Semiconductor SubstratesMany properties of the thin films are different from the bulk value and in many cases, depend dramatically on the film thickness. In the metallic ultra-thin films epitaxially grown on the semiconductor substrate, the conduction electrons are confined by the vacuum and metal-semiconductor interface. When the film thickness is comparable to the electron Fermi wavelength, this confinement will produce discrete energy levels known as quantum well states (QWS), which dramatically modify the electronic structures of the thin film and this is called quantum size effect (QSE). QSE will have a profound effect on a lot of physical properties of the thin films. Among various systems exhibiting QSE, Pb/Si (111) is the most widely studied one and exhibits the richest phenomena in QSE. In this study, a home made low temperature Scanning Tunneling Microscopy/Spectroscopy (LT-STM/S) was used to

study the superconductivities of the Pb thin films. Quantum oscillations of the superconductivity have been observed for the films down to 4 monolayer and the oscillation amplitude increases as the film gets thinner. To resolve the discrepancies between the superconductivities measured with ex-situ transport and in-situ STS. We also studied the influence of Au overlay on the Pb thin films with LT-STM/S, and found out the deposition of Au on Pb dramatically roughened the Pb films. Finally, we successfully grew large scale near perfect 2ML Pb films. There are two types of films which exhibit different Moiré patterns. LT-STS studies revealed there is big difference in the superconductivity Tc of these two films, both of which decreased dramatically from that of the 4ML film.Low Temperature Scanning Tunneling Microscope Development: Investigations of Au(111) and Ultra-slow Vortex Dynamics of NbSe2Design of a Low-temperature Scanning Tunneling Microscope System Used to Examine Graphene Nanomembranes Investigation of Low-dimensional Supramolecular Architectures by Low-temperature Scanning

Tunneling MicroscopyLow Temperature Scanning Tunneling Spectroscopy of Different Individual Impurities on GaAs (110) Surface and in Subsurface LayersThe present work presents the results of low temperature STM and STS investigations of (110) surface of GaAs monocrystals doped with impurities of different kind.Heavily Doped III-V Semiconductors Studied by Low-temperature Scanning Tunneling MicroscopyMicrowave Surface Impedance Measurements on Heavy Fermion Superconductor UBe13 and Low Temperature Scanning Tunneling MicroscopyThe second part of this work gives a detailed description of the development of a low temperature scanning tunneling microscope. Although many groups using various approaches have worked on this subject, the design of a high performance low temperature scanning tunneling microscope (LTSTM) is still very challenging. We present here the design of our LTSTM, which has a special configuration and can be mounted on one of our dilution refrigerator cryostats. The system also employs a novel and effective vibration-

isolating mechanism. We also present images obtained with this instrument.Low Temperature Scanning Tunneling Microscope Investigation of Morphology and Electronic Properties of Monolayer Mos2 Grown by Chemical Vapor DepositionSpatially Resolved Low-Temperature Scanning Tunneling Spectroscopy on AuFe Spin-Glass FilmsIn this contribution, we will demonstrate the possibility to study size effects in thin films of AuFe spin-glass alloys by investigating the differential conductance near the Fermi level with low-temperature scanning tunneling spectroscopy (STS). As confirmed by point contact expenments, the voltage dependence of the differential conductance can be directly linked to the tempereture dependence of the resistivity 8. The STS measurements provide the unique possibility to probe possible spatial variations of the size effects. Moreoven combining the STS measurements with topographic scanning tunneling micrescopy (STM) images of the surface may allow to check the influence of the local surface roughness on the spin scattering processes.Scanning Tunneling

Microscopy Study of Low Temperature Silicon Epitaxy on H/Si(001) and Phosphine Adsorption on Si(111)-7x7Low Temperature Scanning Tunneling Microscope Study of Low-dimensional Superconductivity on Metallic NanostructuressSuperconductivity is a remarkable quantum phenomenon in which a macroscopic number of electrons form a condensate of Cooper pairs that can be described by a single quantum wave function. According to the celebrated Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity, there is a minimum length scale (the coherence length) below which the condensate has a rigid quantum phase. The fate of superconductivity in a system with spatial dimensions smaller than [the coherence length] has been the subject of intense interest for decades and recent studies of superconductivity in ultra-thin epitaxial metal films have revealed some surprising behaviors in light of BCS theory. Notably, it was found that superconductivity remains robust in thin lead films with thicknesses orders of magnitude smaller than the coherence length (i.e. in the extreme two dimensional

limit). Such studies raise the critical question: what happens to superconductivity as all dimensions are reduced toward the zero dimensional limit? By controlling the lateral size of ultra thin 2D islands, we systematically address this fundamental question with a detailed scanning tunneling microscopy/spectroscopy study. We show that as the lateral dimension is reduced, the strength of the superconducting order parameter is also reduced, at first slowly for dimensions larger than the bulk coherence length, and then dramatically at a critical length scale of ~ 40nm. We find this length scale corresponds to the lateral decay length of the order parameter in an island containing regions of different heights and different superconducting strength. Overall, our results suggest that fluctuation corrections to the BCS theory are important in our samples and may need to be systematically addressed by theory.Ultra High Vacuum Low Temperature Scanning Tunneling Microscope for Single Atom Manipulation on Molecular Beam Epitaxy Grown SamplesInvestigations of Charging Effects and High-T[subscript]c Superconductivity with Low

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Investigation of Low-dimensional Supramolecular Architectures by Low-temperature Scanning Tunneling Microscopy

To expand the capabilities of the microwave frequency alternating current scanning tunneling microscope to include the ability to study isolated adsorbates and highly reactive surfaces, we have developed a low temperature, ultrahigh vacuum alternating current scanning tunneling microscope. In this alternating current scanning tunneling microscope, we employ the reliable beetle-style sample approach mechanism with a number of other components unique to a low temperature scanning tunneling microscope. These include the sample transfer, delivery, retrieval, storage, sputtering, and heating systems. This alternating current scanning tunneling microscope has been operated at 77K and 4K.

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