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I. Knittel and U. Hartmann
INTERPLAY BETWEEN DOMAIN-WALL RESISTANCE AND SURFACE SCATTERING IN FERROMAGNETIC THIN FILMS

A positive domain-wall resistance at low temperatures has been reported in the literature for cobalt films with a perpendicular magnetic easy axis, in contrast to the behavior observed in microstructures made from cobalt, iron, and permalloy films with an in-plane easy axis and to that seen in perpendicular iron–palladium thin-film compounds. This phenomenon is unexpected if only domain-wall or Fermi-surface properties are considered. It can, however, be understood if an existing domain-wall resistance is considered which is compensated by a magnetoresistance effect arising from surface scattering in a thin film with closure domains. A theory that properly accounts for this interplay between domain-wall resistance and surface scattering is presented and employed to analyze existing experimental data.

Appl. Phys. A ***78****, 359 (2004)*

H. Zhang, H. Grzeschik, P. Sarkar, M. Springborg, and U. Hartmann
ENERGY-LEVEL SPLITTING OF LIGAND-STABILIZED AU55 CLUSTERS OBSERVED BY LOW-TEMPERATURE SCANNING TUNNELING SPECTROSCOPY

Low-temperature ultrahigh-vacuum scanning tunneling microscopy and spectroscopy were employed to analyze the electronic structure of Au55 clusters stabilized by [P(C6H5)3]12C16 ligands. It is important to investigate the clusters at low temperature. Under this condition the thermal motion of the clusters as well as the thermal drift of the STM are sufficiently reduced, so that measurements can be performed reproducibly with highest spatial and spectroscopic resolution. A monolayer of clusters was prepared on an Au(111) surface. Within many small areas (ca. 50 nm^2) the clusters are arranged in a rather perfect hexagonal closest packing. Clusters located within such areas were chosen for further STM and STS investigations since they are largely immobile. At 7 K we imaged for the first time the actual arrangement of the C6H5 rings of the ligand molecules. Spectroscopic data acquired from different locations within a cluster reveal discrete energy levels which can be attributed to the Au55 core. The electronic states of the ligand molecules do not show significant influence on the tunneling spectra. The results are acquired from a series of measurements on the clusters as well as on the ligand molecules. The individual energy-level spacings in vicinity to the Fermi level can be deduced then from the bias ratio of the double tunnel-junction (tip-cluster and cluster-substrate). The latter was determined by accompanying current-distance STM measurements. Experimental results are compared with those obtained by tight-binding calculations.

STM03 Conf. Eindhoven, Eds. P. M. Koenraad and Kemerink, AIP Conf. Proc. ***696****, 795 (2004)*

D. Mautes, H. Zhang, and U. Hartmann
SYMMETRY-BREAK-INDUCED VARIATION OF ENERGY-LEVEL DEGENERACY OBSERVED ON INDIVIDUAL MOLECULES BY LOW-TEMPERATURE STM

In order to experimentally analyze the influence of a small symmetry break on the degeneracy of discrete energy levels we have carried out comparative STM/STS investigations on benzene [C6H6] and triphenylphosphine [P(C6H5)3] molecules adsorbed to Au(111) surfaces. Due to the high symmetry of benzene, most of its energy levels are degenerated. The phenyl rings [C6H5] of P(C6H5)3 are structurally identical with benzene except the substituted H-atom, which is replaced by a P-atom. Therefore P(C6H5)3 should exhibit an additional splitting of certain energy levels due to the slightly reduced symmetry. A similar behavior has already been observed in UPS spectra of bromobenzene [C6H5Br]. The measurements were performed with a variable-temperature UHV-STM system. By using a continuous flow cryostat the microscope can be operated between 6.5 K and room temperature. From the experimentally obtained I-V-data the energy level distribution is derived for both molecules. In this way a symmetry-reduction-induced decrease of the level degeneracy can be observed in detail and compared with theoretical results.

STM03 Conf. Eindhoven, Eds. P. M. Koenraad and Kemerink, AIP Conf. Proc. ***696****, 979 (2004)*

A. Englisch, R. Schön and U. Hartmann
SNOM SET-UP TO STUDY SURFACE PLASMONS ON NANOSTRUCTURED SURFACES

The detection of molecular layers on surfaces can be based on a measurement of the dispersion relation of surface plasmons, two-dimensional solutions of Maxwell's equations at a metal-dielectric interface. To reduce the area, which absorbs molecu1es, plasmon propagation in microstructured metal films can be used. In this context it is of particu1ar interest, how light in nanostructures can be guides without considerable losses. For this purpose a SNOM set-up, based on a commercia1 AFM head, was developed with a tune-fork distance regu1ation various probes can be used to col1ect the evanescent fields. The plasmons are exited by coup1ing 1ight of varying wavelength under attenuated total-ref1ection conditions into the sample. Samples were prepared in various ways. Electron lithography combined with lift-off as wel1 as scratching with AFM tips were employed to structure metal films. The metallic as well as the dielectric side of the interface can be structured. Plasmon propagation in meta1 nanostructures was studied in dependence of frequency and optical properties of the dielectric medium. Resu1ts mapping the field distribution above theses structures will be presented. An additional approach using structured adsorbates of biomolecules to arrange labeled gold spheres by specific binding will as well be presented.

STM03 Conf. Eindhoven, Eds. P. M. Koenraad and Kemerink, AIP Conf. Proc. ***696****, 211 (2004)*

G. Radu and U. Hartmann
DAMPING CONTRIBUTION IN THE INTERACTION BETWEEN PROBE AND LIGAND-STABILIZED CLUSTERS IN NC-AFM

In recent years, non-contact atomic force microscopy (NC-AFM) became a powerful tool for imaging at high resolution as well as for probing specific surface properties. In this method, the shirt of the resonant frequency of the cantilever, which serves as a frequency determining element, is used for adapting the tip-sample separation. Further atomic-scale information can be obtained by simultaneously measuring the damping of the lever oscillation due to the presence of the surface. The damping is direct related to dissipative interactions between tip and sample. In order to understand the origin of energy dissipation and to distinguish between different dissipation mechanisms, it is useful to measure the dissipation as a function of tip-sample distance (dissipation spectroscopy). A knowledge of the involved dissipation contributions provides information on atomic-scale characteristics of the respective sample. Monolayers of ligand-stabilized Au55 clusters were prepared on different substrates such as mica, HOPG, Au(111) as described in. High resolution NC-AFM images showing the individual cluster of 2 nm diameter were obtained of a particular interest is the interaction between the tip and the ligand shell (PPh3) of the clusters. Dissipative interactions are expected. Site-specific dissipation-versus-distance measurements on cluster-covered as well as uncovered areas of the substrate have been performed. An abrupt increasing of dissipation in close proximity to the surface was found in any case. There are different dependences of dissipation on the probe-sample distance on covered und uncovered areas as well as on different substrates. Exponential and power-law dependences of dissipation on the distance for mica and HOPG as mentioned in and were found. A combination of power-law and exponential dependences was found for the clusters. A model will be presented which relates the dissipation to specific properties of the ligand shell.

STM03 Conf. Eindhoven, Eds. P. M. Koenraad and Kemerink, AIP Conf. Proc. ***696****, 899 (2004)*

H. Zhang, G. Schmid, and U. Hartmann
ENERGY-LEVEL SPLITTING OF LIGAND-STABILIZED AU55 CLUSTERS OBSERVED BY SCANNING TUNNELING MICROSCOPY

A monolayer of Au_{55} clusters stabilized by $[P(C_6H_5)_3]_{12}Cl_6$ ligands was investigated at 7 K using a low-temperature ultrahigh vacuum scanning tunneling microscope. The topography of single clusters shows the actual arrangement of the C_6H_5 rings of ligand molecules. Characteristic charge-quantization phenomena usually obtained for metal particles were observed by current–voltage measurements. Spectroscopic data acquired at different locations within a cluster reveal energy levels with average spacing of 170 meV which can be attributed to the Au_{55} core.

Appl. Phys. Lett. ***84****, 1543 (2004)*

U. Hartmann
SCANNING PROBE METHODS FOR MAGNETIC IMAGING
in: ***Magnetic Microscopies of Nanostructures****, H. Hopster and H.P. Oepen (Eds.), Springer, Heidelberg, 2004)*

M. Oberringer, B. Heinz, A. Englisch, H. Gao, T. Martin, and U. Hartmann
ATOMIC FORCE MICROSCOPY AND SCANNING NEAR-FIELD OPTICAL MICROSCOPY STUDIES ON THE CHARACTERIZATION OF HUMAN METAPHASE CHROMOSOMES
Euro. Biophys. J. ***32****, 620(2004)*

M. R. Koblischka, U. Hartmann and T. Sulzbach
IMPROVING THE LATERAL RESOLUTION OF THE MFM TECHNIQUE TO THE 10 NM RANGE

A powerful tool to investigate the magnetic properties of harddisk heads in the range of about 10 nm is demanded by magnetic data storage industry. Magnetic force microscopy (MFM) tips are prepared using the electron-beam deposition technique, which reaches the highest spatial resolution, but is not well suited for batch production. Therefore, also FIB milling is employed to produce MFM tips with a high aspect ratio similar to electron-beam deposition tips. We show that both types of tips not only improve the spatial resolution, but also considerably reduce perturbation effects on soft magnetic structures.

Proc. ICM, Rome, Italy, 2003; J. Magn. Magn. Mat. ***272-276****, 2138 (2004)*

I. Knittel, S. Faas, M. A. Gothe, M. R. Koblischka and U. Hartmann
DOMAIN-WALL RESISTANCE AT LOW TEMPERATURE

The physical origin of domain-wall resistance in thin films at low temperature is still unclear. In order to distinguish between spin-dependent phenomena and effects of the Lorentz force as origin of low-temperature domain-wall resistance, a dedicated experiment was developed. Additionally, models of ballistic transport in thin films with surface scattering and domain structure are discussed. As a result, at least part of the observed domain-wall resistance at low temperature can be attributed to surface scattering.

Proc. ICM, Rome, Italy, 2003; J. Magn. Magn. Mat. ***272-276 Supplement 1****, E1431 (2004)*

Y. Xu, K. Steenbeck, P. Das, J. Wei, M. R. Koblischka and U. Hartmann
LOCAL ELECTRONIC PROPERTIES OF MANGANITE FILMS STUDIED BY STM/STS UNDER AMBIENT CONDITIONS

Thin films of La0.67Sr0.33MnO3 and La0.7Sr0.3MnO3 were prepared by different sputtering techniques. All films show a significant magnetoresistive effect. The topographic and electronic properties of the films were studied by STM/STS under ambient conditions. The local conductance of different films and of spatially separated areas on a film was measured. A surprisingly high degree of homogeneity was found in contrast to previous comparable experiments.

Proc. ICM, Rome, Italy, 2003; J. Magn. Magn. Mat. ***272-276 Supplement 1****, E875 (2004)*

J. Hu, Y. Zhang, B. Li, H. Gao, U. Hartmann and M. Li
NANOMANIPULATION OF SINGLE DNA MOLECULES AND ITS APPLICATION

In this short review paper we briefly introduce recent results from our research work on the manipulation of single biological molecules deposited on the surface of mica by using scanning force microscopes: results of a cooperation between the Shanghai joint group and the University of Saarland on the manipulation of single DNA molecules and some possible applications based on single molecule manipulation and structural characterization. These results emanate from the Shanghai research teams in studying DNA molecular combing, cutting, pushing and pick-up. Future prospects are briefly outlined.

Surface and Interface Analysis ***36****, 124 (2004)*

W. Metzger, M. Oberringer, J. Hu, M. Li, and U. Hartmann
NANOSCALE ANALYSIS OF BIOFUNCTIONAL MOLECULES AND COMPONENTS

In basic medical research, as well as in concrete clinical applications, the nanoscale analysis of biofunctional units is of strongly increasing relevance. Dedicated investigations on molecules, molecular composites or functional units can efficiently be performed ex or in situ by scanning probe methods and, namely, by scanning force microscopy. In the following investigations, the folding behavior of DNA is presented as an example of basic research in medicine. In contrast, the investigation of bioadsorption phenomena in systems on which apheresis therapies are based provides a real contribution to applied medicine.

Proc. NanoMed Conf., Berlin, Germany, 2003; J. Nanoscience and Technology ***4****, 498ff (2004)*

A. Englisch and U. Hartmann
LICHTAUSBREITUNG IN METALLEN?
Magazin Forschung ***2****, 28 (2004)*