Scanning Probe Microscopy Focus Topic
Room: 202 C - Session SP+AS+BI+EM+MI+NS+SE+SS-ThA

Probe-sample Interactions, Nano-manipulation and Emerging Instrument Formats

2:00pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA1 Antibody Movement on Regular Antigen Clusters: Fab Arms are Made for Walking**, *J. Preiner*, Johannes Kepler Univ. & Ctr for Adv. Bioanalysis GmbH, Austria, *N. Kodera*, Kanazawa Univ., Japan, *J. Tang*, Chinese Academy of Sciences, *A. Ebner*, Johannes Kepler Univ., Austria, *M. Brameshuber*, Vienna Univ. of Tech., Austria, *D. Blaas*, Medical Univ. of Vienna, Austria, *N. Ilk*, Univ. of Natural Resources & Applied Life Sci. Vienna, Austria, *H.J. Gruber*, Johannes Kepler Univ., Austria, *T. Ando*, Kanazawa Univ., Japan, ***P. Hinterdorfer***, Johannes Kepler Univ. & Ctr for Adv. Bioanalysis GmbH, Austria **INVITED**

Antibodies are key molecules for the immune system of vertebrates. The Y-shaped IgGs exhibit C2-symmetry; their Fc stem is connected to two identical Fab arms binding antigens. The Fc part is recognized by the complement system and by phagocytic cells. Antibodies can be considered molecular calipers; bivalent binding of the two Fab arms to adjacent antigens can only occur within a distance of roughly 6 to 12 nm. This leads to much higher avidity and slower dissociation rates as compared to monovalent binding. Here we show that antibodies exhibit "bipedal" walking on antigenic surfaces and static binding of both Fab arms of an antibody may hold true only for a time scale of ~ 0.04 s. The walking speed depends on the lateral spacing and symmetry of the antigens. On 2D-crystalline surfaces, such as found on bacteria and viruses, steric strain thus appears to be the main reason for short-lived bivalent binding. Importantly, the collision between randomly walking antibodies was seen to reduce their motional freedom. It leads to formation of transient antibody clusters even at low antibody density. Interestingly, such assemblies are known nucleation sites for docking of the complement system and/or phagocytes.

2:40pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA3 Development of a Novel Single-Molecule Force Based Approach for Fragment Screening**, ***G.A. Milson***, University of Nottingham, UK

The discovery and development of new chemical entities is complex and time consuming, and of great expense to the pharmaceutical industry[1]. High throughput screening (HTS) is the main method used for lead identification, allowing significant numbers of compounds to be tested. However, productivity levels are still below those desired[2]. Due to this, interest in a relatively new process termed fragment based drug discovery (FBDD) has developed[3]. The FBDD process starts from small, efficiently binding fragments elaborated to more drug-like molecules[4]. However, with fragments being smaller components of the traditionally screened small molecules they have lower affinities and as a result require sensitive detection systems[5].

It has been proposed that the atomic force microscope (AFM) could be used as a novel system in fragment screening. The AFM benefits from the ability to probe single molecular interactions[6] using only small volumes of solution that need not be of high purity. Single molecule force recognition spectroscopy (SMFRS) is the commonly termed process where an AFM tip is functionalised with probe molecules that are known to recognise specific target molecules on the opposing surface. Fragments can theoretically be screened against their potential target on the surface and if they bind will block the natural ligand on the tip from occupying the active site.

Here, the well-characterised interaction between streptavidin and biotin was used as a model in which fragments of biotin were screened using an AFM probe functionalized with a biotin-mimetic peptide. It was seen that the AFM was capable of measuring the specific interaction between the biotin mimetic peptide and streptavidin. Each competition assay worked well, with the peptide-streptavidin interaction being blocked by fragments in a concentration dependent manner. Analysis of the percentage adhesion-versus-concentration data resulted in a ranking of the fragments, which matched their known or measured affinities to streptavidin. Despite the fact that this is still in the early stages of development, the results are promising and it is hoped that with further development the approach will be introduced into drug discovery fragment screening methods.

References:

1. Murray, C. W. & Rees, D. C. T , 187-192, (2009).

2. Campbell, S. F. , 255-260, (2000).

3. Chessari, G. & Woodhead, A. J. , 668-675, (2009).

4. Schulz, M. N. & Hubbard, R. E. , 615-621, (2009).

5. Murray, C. W., Verdonk, M. L. & Rees, D. C. , 224-232, (2012).

6. Barattin, R. & Voyer, N. , 1513-1532, (2008).

3:00pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA4 Popping Nano-Balloons on TiO_2(110) Surface with the STM Tip**, ***D.V. Potapenko***, *Z. Li*, *R.M. Osgood*, Columbia University

Argon-filled subsurface nano-cavities can be created on TiO_2 rutile(110) surface by the means of Ar-ion bombardment combined with temperature treatment of the sample. The presence of the nano-cavities is manifested by the elliptical protrusions on the surface up to 1 nm high and 5 – 30 nm wide. We have developed a micromechanical model that can predict the shape and the depth of individual nano-cavities from the geometry of the corresponding protrusions. To evaluate the validity of the model 7 – 9 V, 1 – 10 ms voltage pulses from the STM tip were used to cause controllable explosions of the nano-cavities, thus allowing the direct independent measurements of their depth. The explosions are caused by the combination of local heating due to the voltage pulse and the high mechanical strain of the TiO_2 crystal lattice in the volume of the protrusion. We discuss the general mechanisms of the nanoscale surface modification produced by voltage pulses from the STM tip and show that at certain conditions the mechanical contact between the tip and the surface occurs. This work is an example of an unusual application of scanning probe microscopy for deep subsurface exploration.

3:40pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA6 Manipulating Magnetism One Atom at a Time**, ***S. Loth***, Center for Free-Electron Laser Science, Germany **INVITED**

Magnetic materials consist of atoms that interact very locally – often on atomic length scales. In nanoscopic systems the details of these interactions become increasingly important. We use scanning tunneling microscopy to test how far classical concepts of magnetism can be extended into the nanoworld and how they emerge from the quantum mechanical behavior of individual spins.

We have developed a complete toolset to explore magnetization dynamics in artificial few-atom nanostructures:

Magnetic atoms can be assembled into precisely defined arrays by atom manipulation with the STM tip. The atomic spins interact with each other and form collective magnetic states that can be tailored by modifying the atomic arrangements. Elastic and inelastic electron tunneling spectroscopy is used to quantify magnetic properties such as excitation energies, anisotropy barriers and spin-polarization as the nanostructure is being built up [1]. Crucial information on the stability of a nanostructure and influence of the environment can be obtained from the spin system's dynamical response to an external stimulus. For this purpose we use an all-electronic pump probe measurement scheme that excites the nanostructure repeatedly by spin-transfer torque and measures its response by spin-polarized tunneling [2].

With this technique we identified a new route to create stable magnetic states using antiferromagnetic spin-spin interaction. While individual Fe atoms exhibit a spin relaxation time on the order of 1 ns, linear antiferromagnetic chains with as few as eight Fe atoms show magnetic states that are stable for several minutes [3]. This dramatic change in dynamic behavior is indicative of a cross-over from quantum mechanical spin states to a ground state with classical magnetic order.

These experiments show a promising route towards rapid prototyping of quantum magnetic spin structures with control over static and dynamic properties by atom assembly in the STM.

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[2] S. Loth, M. Etzkorn, C. P. Lutz, D. M. Eigler, A. J. Heinrich, Science 329, 1628 (2010).

[3] S. Loth, S. Baumann, C. P. Lutz, D. M. Eigler, A. J. Heinrich, Science 335, 196 (2012).

4:20pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA8 High-speed AFM with a Light Touch**, ***M. Miles***, *R. Harniman, D.J. Phillips, L.M. Picco, O. Payton, M. Antognozzi, S. Simpson, S. Hanna, D.J. Engledew*, University of Bristol, UK, *G. Gibson, R. Bowman, M.J. Padgett*, University of Glasgow, UK **INVITED**

AFM offers unique characteristics amongst microscopy techniques, and offers many benefits such has high-resolution 3D imaging in many environments including liquids. However, there are three areas in which

conventional AFM has limitations: (i) a low imaging rate, (ii) the probe-sample force interaction, and (iii) the planar nature of the sample. We are developing two high-speed force microscopy techniques to overcome the first two of these, (i) and (ii).

(i) One high-speed AFM (HS AFM) technique is a DC mode in which an automatic feedback mechanism essentially arising from the hydrodynamics of the situation maintains a tip-specimen separation of about 1 nm. This technique routinely allows video-rate imaging and has achieved imaging at over 1000 fps. Damage to specimens resulting from this high-speed DC-mode imaging is surprisingly less than at normal speeds. The behavior of the cantilever and tip at these high velocities has been investigated and super lubricity is a key component in the success of this technique [1,2].

(ii) The second high-speed force microscope is a non-contact method based on shear-force microscopy (ShFM). In this HS ShFM, a vertically-oriented, laterally-oscillating probe detects the sample surface at about 1 nm from it as a result of the change in the mechanical properties of the water confined between the probe tip and the sample. With this technique, very low normal forces are applied to the specimen. Information on the molecular water layers as a function of position [3,4].

(iii) AFMs require planar samples because the probe scans in a plane. The tip only 'sees' the sample from above. We have overcome this limitation by steering the tip of a nanorod in a three dimensional scan with six degrees of freedom using holographically generated traps such that it is possible to scan around a sample from any direction. We use various probe types: including silica nanorods, rod-like diatoms, and two-photon polymerized 3D structures [5,6].

1. Payton, OD, et al., Nanotechnology 23 (2012) Art. No. 265702.

2. Kalpetek, P, et al., Measurement Sci. & Technol., 24 (2013) Art. No. 025006.

3. Harniman RL, et al., Nanotechnology 23 (2012) Art. No. 085703.

4. Fletcher, J, et al., Science 340 (2013) online April 11th.

5. Phillips DB, et al., Nanotechnology 22 (2011) Art. No. 285503.

6. Olof SN et al., Nano Letters 12 (2012) 6018-6023.

5:00pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA10 Multimodal and Multispectral Nano-imaging: Accessing the Structure Underlying the Function of Polymers, organic Photovoltaics, and Biomaterials**, ***M.B. Raschke***, University of Colorado at Boulder **INVITED**

The properties of many functional soft-matter systems, including polymer heterostructures, organic photovoltaics, and biomembranes are typically defined on the mesoscopic few nm to sub-micron scale. Scattering scanning near-field optical microscopy (s-SNOM) has demonstrated its ability to access the relevant spatial regime. In combination with IR-vibrational spectroscopy s-SNOM provides molecular structural information. However, a yet higher degree of specificity, sensitivity, and selectivity with respect to specific molecular functional features is desired. We will discuss the combination of scattering scanning near-field optical microscopy (s-SNOM) with other nano-optical and scanning probe modalities. That together with the multi-spectral features of different coherent and incoherent IR sources including tunable continuous-wave lasers, femtosecond sources, broadband synchrotron radiation, and thermal near-field radiation provides the desired enhanced dynamic range to probe at the level of the intra- and intermolecular interaction. This results in a unprecedented degree of specificity, sensitivity, and selectivity with respect to specific molecular functional features, as we will discuss for several specific block-copolymer, organic photovoltaic, protein, self-assembled monolayer, and biomineral systems we investigated.

5:40pm **SP+AS+BI+EM+MI+NS+SE+SS-ThA12 Mapping Local Dipole Domains within Two-Dimensional Plastic Lattices**, ***J.C. Thomas***, *J.J. Schwartz, H.S. Auluck, G. Tran, J. Gilles, S. Osher*, University of California at Los Angeles, *C.A. Mirkin*, Northwestern University, *P.S. Weiss*, University of California at Los Angeles

We have observed aligned dipoles forming two-dimensional plastic lattices in self-assembled monolayers of carboranethiols on Au{111}. We have used scanning tunneling microscopy (STM) and simultaneously acquired local barrier height images of 9,12-dicarba-*closo*-dodecaborane *o*-9-carboranethiol (**O9**) monolayers on Au{111} at 4K in extreme high vacuum to determine the local structures and dipole orientations within the monolayers. The molecular structure of **O9** is that of a symmetric cage; a two-dimensional plastic lattice of aligned dipoles is formed through favorable intermolecular dipole-dipole interactions after chemisorption. Local barrier height images juxtaposed with the simultaneously recorded topography reveal directional dipole offsets within domains. New imaging analysis methods were used to overlay the multimodal data and determine molecular dipole orientations. We employ Monte Carlo simulations to model the dipole-dipole interactions, and to predict alignment at low temperature. We compare and contrast topographic and simultaneously acquired local barrier height images of 1,7-dicarba-*closo*-dodecaborane *m*-1-carboranethiol (**M9**) on Au{[111} in which the largest dipole is due to the sulfur-gold bond (as opposed to the cage) and is aligned to topographic maxima in STM images.

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