

O 54: Focus Session: Scanning Probe Microscopy with Quartz Sensors II

Time: Wednesday 15:00–17:30

Location: CHE 89

Topical Talk

O 54.1 Wed 15:00 CHE 89

Peering into interfacial water by qPlus-based atomic force microscopy — ●YING JIANG — International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, P. R. China

Water/solid interfaces are a central theme across an incredibly broad range of scientific and technological processes. Scanning probe microscopy (SPM) has been extensively applied to probe interfacial water, but there exist two longstanding limitations in the past decades, which makes SPM fall short compared with conventional spectroscopic methods. First, it is very difficult to image H atoms of water molecule directly; Second, it is highly possible to disturb the fragile H-bonding water structure during the imaging process. To this end, we have developed a new imaging method based on qPlus-type atomic force microscopy (AFM), which is sensitive to H and non-invasive to water structure. The key lies in probing the high-order electrostatic force between the quadrupole-like CO-terminated tip and the polar water molecules at large tip-water distances. In this talk, I will showcase the application of this technique to probe water clusters, ion hydrates, 2D ice and even bulk ice surface [1-4]. The possibility of combing qPlus-AFM with quantum sensing technology to perform nanoscale NMR measurement of interfacial water will be also briefly discussed [5-6].

[1] Nature Commun. 9, 122 (2018) [2] Nature 557, 701 (2018) [3] Nature 577, 60 (2020) [4] Science 377, 315 (2022) [5] Nature Commun. 12, 2457 (2021) [6] Nature Physics 18, 1317 (2022)

O 54.2 Wed 15:30 CHE 89

Does surface adsorption change the reactivity of an organic molecule? — JACK HENRY, PHILIP BLOWEY, and ●ADAM SWEETMAN — University of Leeds, United Kingdom

Adsorption onto metal surfaces is known to alter the electronic [1], and geometric [2] structure of small organic molecules. However, the change in reactivity of a single molecule induced by the presence of a surface is less well studied. We investigated the influence of molecule-substrate bonding on the interactions experienced by a scanning probe microscope (SPM) tip by studying C60 molecules adsorbed in different configurations [3-5] on the Cu(111) surface, using qPlus NC-AFM/STM at 5K. We compare the minima in collected force spectra to complementary ab initio (DFT) simulations, and discuss the substantial differences in our results compared to the existing literature [3]. 1. Repp, J., et al. (2005). Physical Review Letters, 94(2), 026803. 2. L. Gross, et al. Science 325, 1110 (2009). 3. Jonathan Brand et al. Nano Letters 2019 19 (11), 7845-7851 4. W. W. Pai, et al. Physical Review Letters 104, (2010). 5. L. Forcieri, et al. Physical Review B 104, (2021).

O 54.3 Wed 15:45 CHE 89

Water Dimer-Driven DNA Base Superstructure with Mismatched Hydrogen Bonding — SHUNING CAI¹, LAURI KURKI¹, ●CHEN XU¹, ADAM S. ADAM^{1,2}, and PETER LILJEROTH¹ — ¹Department of Applied Physics, Aalto University, 00076 Aalto, Espoo, Finland — ²WPI Nano Life Science Institute (WPI-NanoLSI), Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan

The existence of water dimers in equilibrium water vapor at room temperature and their anomalous properties revealed by recent studies suggest the benchmark role of water dimers in both experiments and theory. However, there have been limited observations of individual water dimers due to the challenge of water separation and generation at the single-molecule level. Here, we achieve real-space imaging of individual confined water dimers embedded inside a self-assembled layer of a DNA base, adenine, on Ag(111). The hydration of the adenine layers by these water dimers causes a local surface chiral inversion in such a way that the neighboring homochiral adenine molecules become heterochiral after hydration, resulting in a mismatched hydrogen-bond pattern between neighboring adenine molecules. Furthermore, theoretical simulation and calculations corroborate the mutual influence between the adenine superstructure and these dynamic confined water dimers. The observation of single confined water dimers offers an unprecedented approach to studying the fundamental forms of water clusters and their interaction with the local chemical environment.

O 54.4 Wed 16:00 CHE 89

Nanoscale 3D printing technique by using the nanopipette-combined quartz tuning fork-atomic force microscope — ●SANGMIN AN — Department of Physics, Institute of Photonics and Information Technology, Jeonbuk National University, Jeonju 54896, South Korea

Materials can be classified by hardness, such as gold represented by hard materials having elasticity and water represented by soft materials having viscosity. However, at the nanoscale, even solid gold exhibits viscosity [1], while liquid water also exhibits elasticity [2] revealed by a quartz tuning fork-atomic force microscope (QTF-AFM), which has the intrinsic properties of high stiffness and high sensitivity. In this presentation, I discuss how this QTF-AFM can be applied as the nanoscale 3D printing technique combined with nanopipette [3,4], which are typically used in biotechnology, along with showing the results of the elasticity and viscosity of water. In addition, I share the results of nanoscratching [5] and nanosensor [6] schemes which can be realized with the nanorod-combined QTF-AFM instead of nanopipette.

- [1] Nature 569, 393-397 (2019).
 [2] Phys. Rev. X 8, 041046 (2018).
 [3] Nano-Micro Lett. 14, 13 (2022).
 [4] Nanoscale Adv. in press (2022).
 [5] Appl. Nanosci. 9, 67-76 (2019).
 [6] Proc. Natl. Acad. Sci. USA 115(12), 2884-2889 (2018).

Topical Talk

O 54.5 Wed 16:15 CHE 89

AFM with the qPlus sensor: An ideal tool for oxide surface science — ●ULRIKE DIEBOLD — Institute of Applied Physics, TU Wien, Vienna, Austria

The past decades have seen a sustained interest in the atomic-scale properties of metal oxide surfaces. Local probes are well suited to study surface reconstructions, (point) defects, trapped local charges, and the adsorption of small molecules. Much of the work has focused on semiconducting or (ultra-)thin film samples, as these have sufficient conductivity for STM investigations. The superior resolution afforded by the qPlus sensor allows for extending such studies to highly insulating oxides, such as silicates or other minerals. In the talk, I will give an overview of recent progress, fascinating opportunities, and challenges of atomically-resolved AFM on oxides.

O 54.6 Wed 16:45 CHE 89

Atomic-scale imaging of muscovite mica and its interaction with water — ●GIADA FRANCESCHI¹, PAVEL KOČAN², ANDREA CONTI¹, SEBASTIAN BRANDSTETTER¹, JAN BALAJKA¹, IGOR SOKOLOVIC¹, JIRI PAVELEC¹, MARKUS VALTINER¹, MARTIN SETVIN², FLORIAN MITTENDORFER¹, MICHAEL SCHMID¹, and ULRIKE DIEBOLD¹ — ¹Inst. Appl. Phys., TU Wien, Wiedner Hauptstr. 8-10/E134, 1040 Vienna, Austria — ²Dept. Surface and Plasma Phys., Charles University in Prague, V Holesovickach 2, 180 00 Prague, Czech Republic

Muscovite mica is an abundant potassium aluminosilicate enjoying wide popularity in surface and interfacial science. Its prevalence is partly due to its extraordinary cleaving properties: The easily obtained atomically flat terraces are ideal for fundamental studies. To date, it is established that the cleaved surface is decorated by K⁺ ions,¹ but their intrinsic ordering and their precise hydration mechanisms are not known. Here, we use non-contact atomic force microscopy to image the K⁺ distribution of cleaved mica and investigate their interaction with water under ultra-high vacuum conditions. After cleaving, the ions are arranged with short-range order, which we interpret with support from theory.² Dosing water vapor at 100 K causes various hydration arrangements, consistent with previous theoretical studies, and clustering at increasing water coverage. Exposure to ultra-clean liquid water³ induces ion mobility and substitution by protons. [1] *Christenson et al., Surf. Sci. Reports* 71, 367 (2016). [2] *Franceschi et al., submitted*. [3] *Balajka et al., Rev. Sci. Instrum.* 89, 083906 (2018)

O 54.7 Wed 17:00 CHE 89

Surface structure of dry and hydrated α -Al₂O₃(0001) — JOHANNA HÜTNER¹, DAVID KUGLER^{1,2}, MICHAEL SCHMID¹, ULRIKE DIEBOLD¹, and ●JAN BALAJKA¹ — ¹Institute of Applied Physics, TU Wien, Vienna, Austria — ²CEITEC, Brno, Czech Republic

Corundum α -Al₂O₃ is an important ceramic also widely used as a

support for heterogeneous catalysis. Due to similar Al coordination, α - Al_2O_3 is an important model system for naturally occurring minerals, such as aluminosilicate clays. Detailed studies of alumina surfaces have been stymied by its insulating nature but successfully performed with atomic force microscopy [1]. We used noncontact AFM to investigate the $(\sqrt{31} \times \sqrt{31})\text{R}9^\circ$ -reconstructed $\text{Al}_2\text{O}_3(0001)$ surface formed upon high-temperature annealing. The reactivity of surface sites is strongly affected by hydroxylation. However, complete surface hydroxylation requires high pressures of water vapor (1 Torr) [2] that cannot be easily achieved in a conventional ultrahigh vacuum system. We explored the interaction of the $\text{Al}_2\text{O}_3(0001)$ surface with varying pressures of water vapor as well as ultrapure liquid water dosed with a UHV-compatible dispenser [3]. The results will provide new insights into the hydration of environmental substrates. [1] J. V. Lauritsen, et al., *Phys. Rev. Lett.* 103, 076103 (2009) [2] P. J. Eng, et al., *Science* 288, 1029 (2000) [3] J. Balajka, et al., *Rev. Sci. Instrum.* 89, 8, 083906 (2018)

O 54.8 Wed 17:15 CHE 89

Atomic-scale imaging of the cleaved feldspar microcline (001)

surface and its interaction with water — ●LUCA LEZUO, ANDREA CONTI, JAN BALAJKA, IGOR SOKOLOVIĆ, FLORIAN MITTENDORFER, MICHAEL SCHMID, ULRIKE DIEBOLD, and GIADA FRANCESCHI — Institute of Applied Physics, TU Wien, Wiedner Hauptstrasse 8-10/E134, 1040 Wien, Austria

Feldspar microcline (KAlSi_3O_8), abundant in the Earth's crust and present as dust particles in the atmosphere, is known to be one of the best ice nucleators. The exact processes driving the interaction of microcline with water have been studied intensively [1], but atomic-scale investigations remain elusive.

We present experimental, atomic-scale studies of the microcline-water interaction. The surfaces were prepared by UHV cleaving and analysed with non-contact atomic force microscopy (nc-AFM) and x-ray photoelectron spectroscopy (XPS). The cleaved surface consists of a honeycomb array that we assign to differently back-bonded O atoms. Dosing water vapour at 100 K causes the appearance of a hexagonal lattice and the gradual formation of a connected water network. DFT calculations help us to rationalize our experimental results.

[1] A. Kumar, et al., *Atmos. Chem. Phys.* 18, 7057 (2018)