

“Direct Observation of Dynamic Surface Processes with Scanning Probes”

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This presentation highlights two *dynamic surface processes*, both investigated on the atomic scale with scanning tunneling microscopy. Several ongoing technical developments make scanning probes increasingly suited to observe processes at surfaces rather than static structures. The speed at which processes can be followed is continually improved, the maximum imaging frequencies being pushed presently beyond video rate. The range of conditions under which surfaces can be imaged with scanning probes is also expanding and now includes those for a number of interesting and relevant processes.

The first surface process discussed in this talk has been nick-named “*The Atomic Slide Puzzle*”, and reflects the diffusion of surface vacancies. Usually, surface mobility is thought to be restricted completely to the steps and kinks on crystal surfaces. These sites form the natural locations for atoms to come and go. Atoms in the close-packed terraces are often considered to be completely static, since they are tightly packed by their neighbors. How wrong this static view can be, is demonstrated by measurements that we have performed on the Cu(001) surface, using a high-speed, variable-temperature STM. The close-packed terraces of this metal surface are far from static, even at temperatures as low as room temperature! We make the motion visible of the terrace atoms, by embedding a low density of In atoms in the first Cu layer. The peculiar characteristics of the motion of these “tracer” atoms show that the diffusion of surface vacancies is responsible for a continual reshuffling of all (In and Cu) atoms in the first layer [1-3].

The second process concerns heterogeneous catalysis. We have developed a so-called “*Reactor-STM*”, a small STM that is integrated with a miniature, high-temperature (500 K), high-pressure (5 bar) reactor cell. With this STM we have obtained the first direct, atomic-scale look on model catalyst surfaces under realistic or ‘near-realistic’ reaction conditions, i.e. well beyond the notorious “*pressure gap*”. Reactive gas mixtures flow over the investigated surface, while it is being imaged with the STM. Simultaneously with the imaging, the hot gas mixture, which leaves the reactor, is mass analyzed, so that the relation between structure and chemical activity is revealed directly. Results will be shown for the oxidation of CO on metal surfaces, which demonstrate that under high-pressure conditions the mechanism and kinetics for this important reaction are radically different from those in ultrahigh vacuum [4,5].

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- [1] R. van Gastel, E. Somfai, W. van Saarloos, and J.W.M. Frenken, *Nature* **408** (2000) 665.
 - [2] R. van Gastel, E. Somfai, S.B. van Albada, W. van Saarloos, and J.W.M. Frenken, *Phys.Rev.Lett.* **86** (2001) 1562.
 - [3] R. van Gastel, J.W.M. Frenken, B.S. Swartzentruber, E. Somfai, and W. van Saarloos, in *The Chemical Physics of Solid Surfaces*, Vol. 11, *Surface Dynamics*, ed. D.P. Woodruff, (Elsevier, Amsterdam, 2003).
 - [4] B.L.M. Hendriksen and J.W.M. Frenken, *Phys.Rev.Lett.* **89** (2002) 046101.
 - [5] B.L.M. Hendriksen, S.C. Bobaru, and J.W.M. Frenken, *Surf.Sci.* **552** (2004) 229.