

CHEMICAL IDENTIFICATION OF INDIVIDUAL SURFACE ATOMS USING DYNAMIC FORCE MICROSCOPY

Óscar Custance

Division of Electrical, Electronic and Information Engineering, Graduate School of Engineering, Osaka University, Yamada-oka 2-1, 565-0871 Suita, Osaka, Japan

oscar@afm.eei.eng.osaka-u.ac.jp

The chemical identification of atoms and molecules at surfaces has been pursued from the invention of both scanning tunnelling microscope and atomic force microscope (AFM). The intrinsic detection nature of these techniques has hindered, however, most of the efforts, and chemical recognition of individual atoms in multi-element systems still remains a challenge.

AFM operated in dynamic mode has become a very powerful technique to explore surfaces at atomic scale [1, 2], allowing one even the manipulation of individual atoms [3, 4] for the creation of sophisticated nanostructures [5]. In the most refined experimental set-ups, dynamic force microscopy (DFM) enables as well the precise quantification of the short-range forces associated with the onset of the chemical bonding between the outermost atom of the AFM tip and the individual surface atoms [6, 7]. Since the chemical bonding force between atoms is closely related to their nature, the short-range forces measured with DFM should contain information about the chemical specificity of the different atoms probed. To extract this information is, however, a knotty problem, as the measured short-range forces show a strong variability upon the structure and chemical termination of the AFM tip apex [8].

In this contribution we present a method for the chemical identification of individual surface atoms based on the precise quantification of short-range chemical interaction forces with DFM [9]. We will show that even when these forces are tip-dependent, the relative interaction ratio of the maximum attractive short-range force registered over the different atoms of a heterogeneous surface for a given tip remains constant almost independently from the tip-apex structure and chemical termination. Through this property, tabulated relative interaction ratios can be used as fingerprints for single-atom chemical recognition. We demonstrate this identification method on a particularly challenging system: an alloy composed by three atomic species (silicon, tin and lead) with very similar chemical properties and identical adsorption positions, where any discrimination attempt based solely on topographic measurements would be impossible to achieve.

References:

- [1] F. J. Giessibl, *Rev. Mod. Phys.* **75** (2003) 949.
- [2] R. García and R. Pérez, *Surf. Sci. Rep.* **47** (2002) 197.
- [3] N. Oyabu, O. Custance, I. Yi, Y. Sugawara and S. Morita, *Phys. Rev. Lett.* **90** (2003) 176102.
- [4] Y. Sugimoto, P. Jelinek, P. Pou, M. Abe, S. Morita, R. Pérez and O. Custance, *Phys. Rev. Lett.* **98** (2007) 106104.
- [5] Y. Sugimoto, M. Abe, S. Hirayama, N. Oyabu, O. Custance and S. Morita, *Nature Materials* **4** (2005) 156.
- [6] M. A. Lantz, H. J. Hug, R. Hoffmann, P. J. A. van Schendel, P. Kappenberger, S. Martin, A. Baratoff and H.-J. Güntherodt, *Science* **291** (2001) 2580.
- [7] M. Abe, Y. Sugimoto, O. Custance and S. Morita, *Appl. Phys. Lett.* **87** (2005) 173503.
- [8] N. Oyabu, P. Pou, Y. Sugimoto, P. Jelinek, M. Abe, S. Morita, R. Pérez and O. Custance, *Phys. Rev. Lett.* **96** (2006) 106101.
- [9] Y. Sugimoto, P. Pou, M. Abe, P. Jelinek, R. Pérez, S. Morita, and O. Custance, *Nature* **446** (2007) 64.