Atom-by-Atom: How Nanoclusters Form on a Surface

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In the talk I will discuss the formation of metal nanoclusters on the magnetite $Fe_3O_4(001)$ surface [1]. Using Scanning Tunneling Microscopy (STM), we follow how the nanoclusters evolve from isolated, single metal ad-atoms. This allows conclusions about nucleation and growth phenomena, such as the critical nucleus size or the nature of the mobile species.

The $Fe_3O_4(001)$ surface exhibits a rather stable reconstruction with $(\sqrt{2}x\sqrt{2})R45°$ symmetry that is characterized by a re-arrangement of Fe atoms in the first subsurface layer [2]. This reconstruction creates special surface sites, where metal adatoms adsorb in a bridge-bonded configuration between two undercoordinated surface O atoms, see Fig. 1. As there is only one such site per unit cell, the ad-atoms are ordered and widely spaced.

Stable and isolated ad-atoms were first observed for Au [3], where aggregation into clusters was only observed at temperatures as high as 700 K (which is where the reconstruction is lifted and the the ad-atoms are no longer stabilized [4]). For Ag, a full monolayer of ad-atoms is stable up to the same temperature; the clusters present at higher coverages however act as seeds for agglomeration and reduce the thermal stability of the adatom phase [5]. Another interesting aspect is also the mobility of ad-species induced by gas adsorption, as reported for Pd [6] and observed for Pt and other metals.

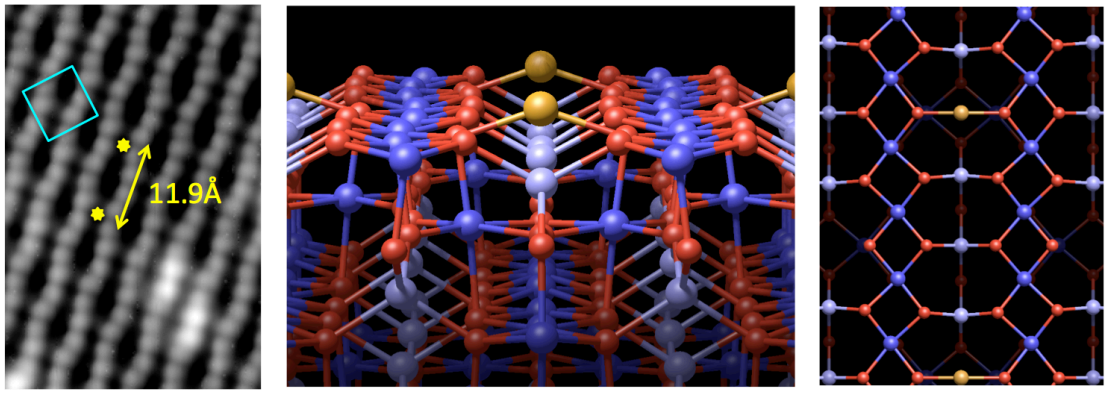

Figure 1: The reconstructed $Fe_3O_4(001)$ serves as a template for isolated, single metal ad-atoms. Left: STM image, surface Fe atoms are observed in undulating rows, in agreement with the model (blue atoms, center). Marked with stars are special sites where vapor-deposited metals preferentially adsorb, as shown for Au (golden).

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[3] Z. Novotny et al., Phys. Rev. Lett. 108, 216103 (2012).
[4] N. Bartelt et al., Phys. Rev. B 88, 235436 (2013).
[5] R. Bliem et al. ACS Nano 8, 7531 (2014).
[6] G.S. Parkinson et al., Nature Mater. 12 (2013) 724