Ultrafast diffusion at the onset of growth: O/Ru

John Kelsall, Nadav Avidor, Andrew Jardine, and John Ellis

University of Cambridge, UK

The mechanisms that underpin growth at surfaces are of wide importance and of particular current interest as 2D materials are explored for applications. The fundamental physics and chemistry at the onset of the growth process (e.g. microscopic nucleation) can be understood via the dynamic equilibrium that exists between clusters and diffusing precursors when a low coverage is maintained at high temperature. Furthermore, although high temperatures are technologically relevant and actually necessary for the production of certain materials (such as hexagonal boron nitride, hBN), there have been almost no investigations of clustering dynamics conducted under such extreme experimental conditions, due to the spatial and temporal resolution required.

Here, we study the diffusion and islanding of oxygen on Ru(0001) using helium-3 spin echo spectroscopy [1], which is able to probe surface dynamics on both nanoscopic length and picosecond time scales. Experimental conditions of high temperature and low surface coverage are used. Previously, room temperature scanning tunnelling microscopy (STM) measurements have demonstrated the clustering of oxygen on Ru(0001) and characterised the oxygen inter-adsorbate interaction [2, 3]. In our work, we have shown that clustering, i.e. some degree of local order, also occurs at temperatures well above the order/disorder transition. We are therefore able to comment on both nucleation and diffusion when ongoing motion is extremely rapid. The present talk will discuss what can be learnt by measuring diffusion in this regime (in this case, 700-900 K), our analysis using analytical methods and Monte Carlo simulations, and the implications for the wider study of growth under these conditions.

[1] A. P. Jardine, H. Hedgeland, G. Alexandrowicz, W. Allison, and J. Ellis, Helium-3 spin-echo: Principles and application to dynamics at surfaces, Progress in Surface Science, 84, 323 (2009)

[2] J. Wintterlin, J. Trost, S. Renisch, R. Schuster, T. Zambelli, and G. Ertl, Real-time STM observations of atomic equilibrium fluctuations in an adsorbate system: O/Ru(0001), Surface Science, 394, 159 (1997)

[3] S. Renisch, R. Schuster, J. Wintterlin, and G. Ertl, Dynamics of adatom motion under the influence of mutual interactions: O/Ru(0001), Phys. Rev. Lett., 82, 3839 (1999)