A QUANTUM-STABILIZED MIRROR FOR ATOMS

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Helium atom scattering is a powerful, well-established technique for investigating the structural and dynamical properties of surfaces [1,2]. Because of the low energies used (10-100 meV), neutral He atoms probe the topmost surface layer of any material in an inert, completely nondestructive manner. This means that a Scanning Helium Atom Microscope (SHeM) using a focused beam of He atoms as imaging probe, would be a unique tool for reflection or transmission microscopy, with a potential lateral resolution of 20-50 nanometers. It could be used to investigate insulating glass surfaces, delicate biological materials and fragile samples which are difficult to examine by other methods because of sample charging or electron excitation effects. The physical realization of such a microscope requires the development of a mirror able to focus a beam of low energy He atoms into a small spot on the sample to be examined. Holst and Allison [3] demonstrated that electrostatic bending of a thin, H-passivated Si(111)-(1×1) crystal was able to focus a 2 mm-He beam to a spot diameter of 210 microns. A serious limitation, however, to improve the resolution was found to be the low intensity obtained in the focused peak, which is a consequence of the poor reflectivity of such surfaces, less than 1%.

Here we show that Quantum Size Effects can be exploited to produce an ultrathin film of Pb of magic thickness on a highly perfect Si(111) thin wafer. Figure 1 shows the surface morphology of a 7.1 ML thick film of Pb deposited at 114 K and annealed to 260 K. The film is atomically flat and most of the surface (94 %) is 7 ML-thick. Only 5 % of the surface is occupied by 9 ML-thick regions (bright areas) and ~1 % for 5 ML-thick regions, imaged as dark small islands. Notice that not a single step is visible in the image. Very large scale STM images indicate that the film at 260 K is atomically flat over lateral scales larger than 10 microns.

In these conditions, the specular reflectivity is 15 % of the incident He beam (at 21 meV) [4], that is, 20 times higher than for Si(111)-H(1×1) passivated surfaces under similar scattering conditions [5] and comparable with the reflectivity of the best metallic single crystals [2]. The diffraction spectrum recorded along the [-110] azimuth, is shown on the left panel of Fig.1. Note that only specular diffraction is observed in the angular distribution, as expected from a close-packed metal surface. A similar spectrum was obtained along the [-12-1] azimuth (not shown). Since all magic thickness achieve similar structural perfection upon annealing, the maximum reflected intensity is approximately the same (7×10^6 c/s) for all magic thicknesses (i.e. 5, 7, 9, 11, 13 MLs) upon heating to the temperature range in which each of them are stable [6,7].

References:

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Figuras:

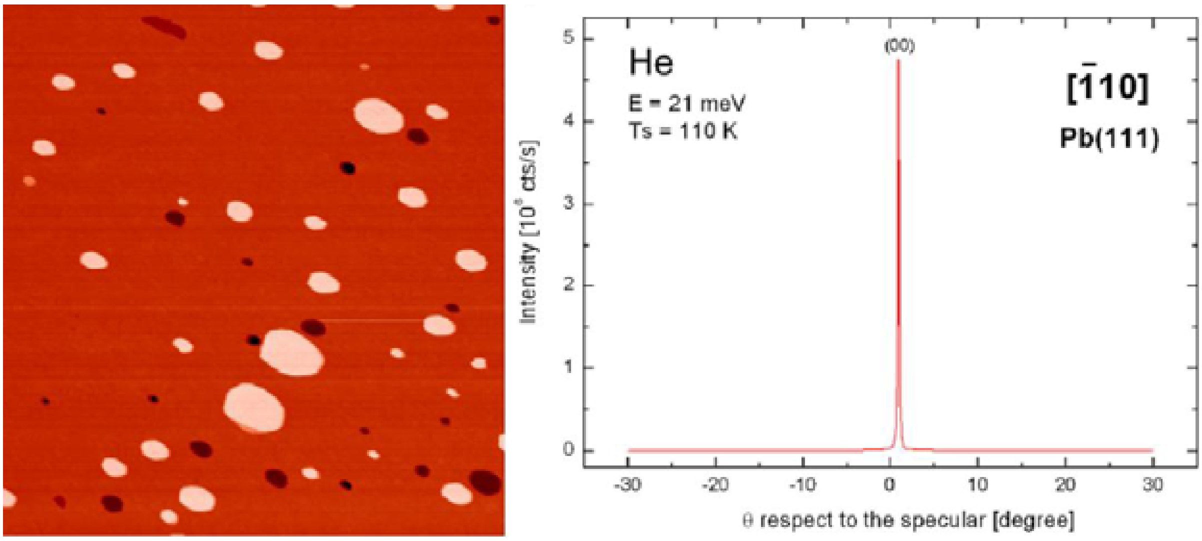

Figure 1 Right: 500 nm × 500 nm STM image of 7ML-thick Pb film deposited at 98K and heated to 260K. Most (94%) of the surface is covered with 7ML. Left: He diffraction spectrum corresponding to a surface covered with 4ML Pb at 110K