PHASE TRANSITIONS IN Pb/Si(111) AND Pb/Ge(111): TRUE VARIABLE TEMPERATURE STM EXPERIMENTS

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Low dimensional systems are an ideal playground for the analysis of critical phenomena. In particular, structural phase transitions occurring on surfaces have been the subject of intense experimental and theoretical research for the last few decades. The development of new experimental techniques such as variable temperature scanning tunneling microscope (VT-STM) has widened, much more recently, our view of the microscopic aspects of some of such transitions. In this talk two examples of the application of VT-STM to the analysis of surface phase transitions at low temperature on two systems, Pb/Si(111) and Pb/Ge(111), will be shown. The analysis of both systems was performed with an ultra-high-vacuum home-made VT-STM [1] that allows imaging of the same surface spot with atomic resolution while varying the sample temperature in a large range so that the evolution from one phase to another can be tracked by recording unusual "true variable temperature" STM movies.

The first example deals with the $(\sqrt{3}x\sqrt{3})R30^{o} \leftrightarrow$ (3x3) phase transition that takes place at low temperature on the 1/3 monolayer Pb on Si(111) system [2, 3]. This phase transition is related to those observed in the iso-electronic Pb/Ge(111) [4] and Sn/Ge(111) [5] systems, whose origin and driving force has been the subject of an intense debate in the last few years [6]. For Pb/Si(111), by tracking exactly the same regions of the surface with atomic resolution in a temperature range between 40 and 200 K, we have observed the phase transition by VT-STM in real time. The ability to prepare and track exceptionally large domains without defects has allowed us to detect the intrinsic character of the phase transition at temperatures around 86 K. This intrinsic character is in full agreement with our first-principles density functional calculations. Moreover, our results show that the hypothesis that point defects play a fundamental role as the driving force, reported for similar systems, can be discarded for Pb/Si(111).

The second example is related to the Pb/Ge(111) system. We have investigated [7] a recently reported structural phase transition at lower temperatures for Pb/Ge(111) [from a (3x3) symmetry to a disordered "glassy"-like phase] [8] using STM. By tracking exactly the same surface regions with atomic resolution while varying the sample temperature from 40 to 140 K, we have observed that substitutional point defects are not mobile, in clear contrast to previous assumptions. Moreover, STM data measured at the lowest temperatures ever reported for this system (10 K) show that while filled-state images display the apparent signature of a glassy phase with no long-range order, in empty-state images honeycomb patterns with (3x3) periodicity, and not distinguishable from data measured at much higher temperatures, are clearly resolved. These new observations cast serious doubts on the nature and/or on the existence of a disordered phase at low temperature [7].

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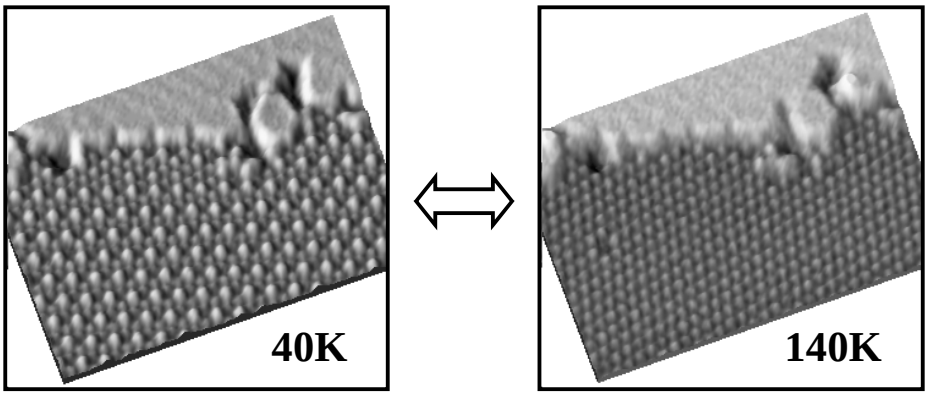
Figure:



Frames extracted from a VT-STM movie measured continuously between 40K and 140K showing exactly the same 20x13nm^2 region below and above the (3x3) to ($\sqrt{3}$x$\sqrt{3}$)*R*30º phase transition in Pb/Si(111) [3].