Graphene on Pt(111) by Noncontact Atomic Force Microscopy at low temperature

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Abstract

Since the discovery of the fascinating properties of free-standing graphene, the scientific community is devoting a huge effort in exploring, both experimentally and theoretically, this true two dimensional material (1). The growth of graphene on metals is being thoroughly investigated both from a perspective focussed on applications, as large-scale monolayer graphene with low defect density can be prepared, (2) as well as from a fundamental point of view, due to the strong substrate-dependent differences found on graphene-metal interactions (3).

Scanning tunneling microscopy (STM) is an ideal approximation to study the atomic-scale electronic properties of graphene (4). However, understanding the atomic structure is rather complicated because of the sensitivity of STM to the local density states near the Fermi level. Noncontact Atomic Force Microscopy (NC-AFM) in Frequency Modulation (FM) mode, where a frequency shift (Δf) from the cantilever resonance frequency at free oscillation is detected, arise as an ideal complementary approach for studying graphene atomic structure on metals since it is a technique sensitive to the interaction force between the tip apex and the outermost sample atoms, which can also lead to very high spatial resolutions (5).

In this contribution, for the first time, NC-AFM measurements with atomic resolution of the graphene/Pt(111) system are reported. We have used a new home-made atomic force microscope operating under ultra-high vacuum conditions at low temperature (5K). Measurements using commercial platinum coated silicon cantilevers (Nanosensors NCL-Pt) show sharp contrast inversion at the atomic scale as the frequency shift is varied, changing from apparent hexagonal patterns (with only one maximum per unit cell) to honeycomb-type patterns (see Fig. 1). The different frequency shifts are related to different average tip-sample distances and, thus, to different interaction. Specific-site force spectroscopy has been used to clarify the relation between attractive and repulsive forces in the tip-sample interaction involved in atomic contrast inversions.

The present experimental results on graphene/Pt(111) are compared to previous measurements on graphene/Ir(111) by Bonenschanscher *et al* (6) as well as to density functional theory calculations by Ondrácek et al. (7), where it was discussed the origin of atomic resolution contrast inversions on free standing graphene in terms of different tip apex terminations.

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Figures

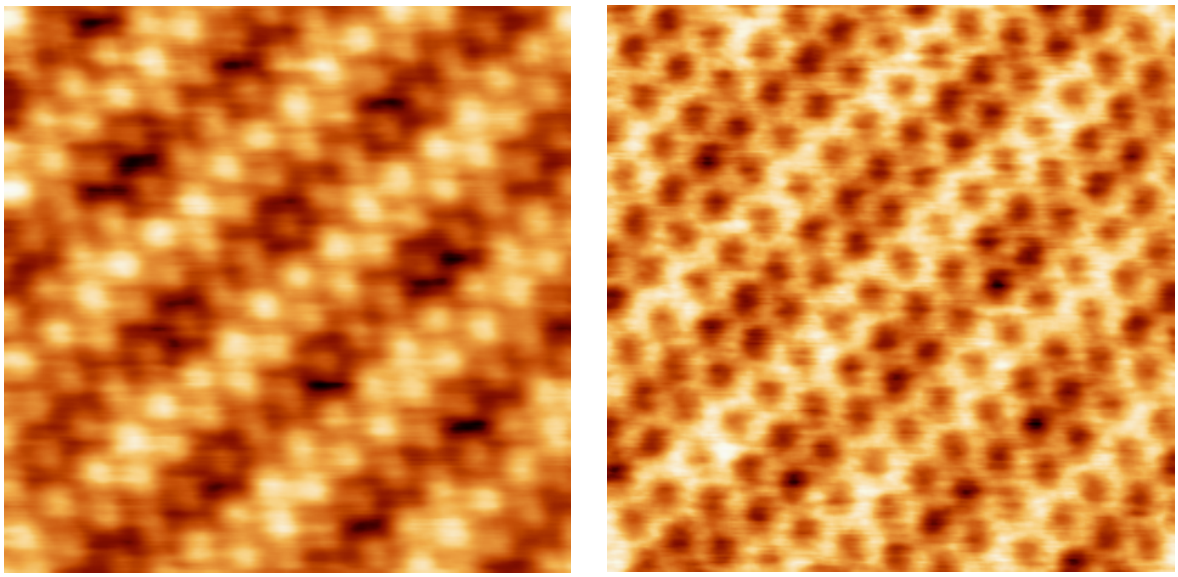

Fig 1. *6x6nm^2 simultaneously recorded atomic resolution NC-AFM images on Graphene/Pt(111); a) Topography image at a set point Δf = -72Hz. A hexagonal lattice with only one maximum per unit cell is observed; b) Simultaneously recorded image at a lower (in absolute value) set point Δf = -62Hz where a honeycomb pattern is detected. Both images were taken using the retrace technique with the WSxM software (8). Oscillation amplitude: 20nm, bias voltage: 0V.*