Graphene growth on Pt(111) and Au(111) using a MBE solid carbon source

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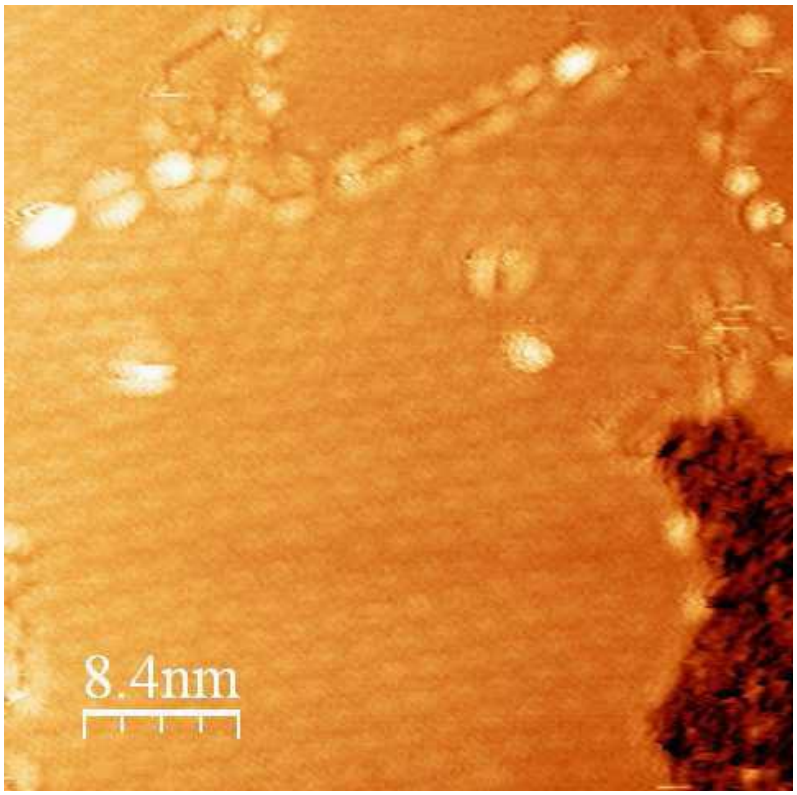
Graphene is considered a prototype material with interesting technological applications and properties [1]. Preparation methods greatly varies from exfoliation mechanical transfer [2] (widely used in research laboratories), to Chemical Vapor Deposition (CVD) [3] (more appropriate for industrial applications). When this later method is used, the catalytic properties of the metallic substrate play a fundamental role during decomposition (cracking of C-H bonds) of hydrocarbons.

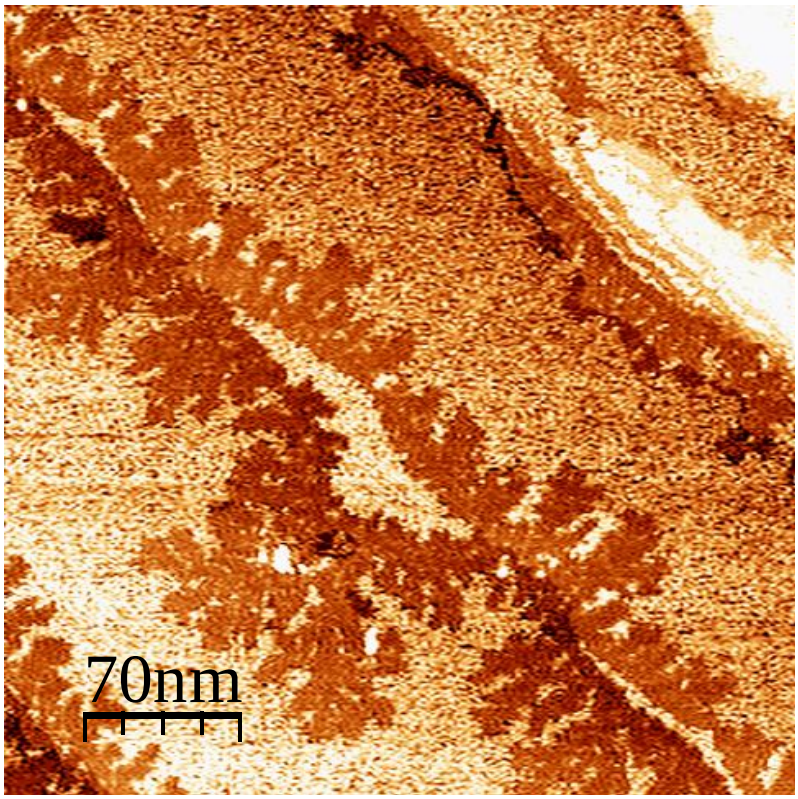
In this work, we present a Molecular Beam Epitaxy (MBE) method to obtain graphene [4] on Pt(111). This procedure uses evaporation of carbon atoms from a carbon solid-source in ultra-high vacuum conditions. We have tested the formation of graphene on several surfaces: from a well establish substrate as platinum, to substrates where graphene can be formed using innovative methods as gold [5]. For the characterization of the graphene layers we have used several *in situ* surface science techniques as low energy electron diffraction (LEED), auger electron spectroscopy (AES) and scanning tunneling microscopy (STM).

The successful evaporation of carbon has been probed on different substrates as platinum, HOPG, and gold. By annealing a Pt(111) and Au(111) surfaces up to 600ºC and 450ºC respectively during carbon evaporation, we have observed a characteristic LEED diagram attributed to graphene [6]. STM images (see figure) display long range ordering of carbon monolayers showing several moirés patterns characteristic of graphene on Pt(111) [7] and islands of dendrites of Au(111) [8], further proving the formation of graphene. This method opens up new possibilities for the formation of graphene on many different substrates with potential technological applications.

[1] Castro Neto, A.H. et al., *Rev. Mod. Phys*., **81** (2009) 109.
[2] Geim, A.K. and Novoselov, K.S. *Nature Mater.*, **6** (2007) 183.
[3] Kim, K.S, et al., *Nature,* **457** (2009) 706-710.
[4] Garcia, J.M. et al., *Solid State Commun.* **152** (2012) 975-978.
[5] Martinez-Galera, A.J. et al., *Nano Lett.*, **11** (2011) 3576.
[6] Sutter, P. et al., *Phys. Rev. B,* **80** (2009) 245411.
[7] Merino, P. et al., *ACS Nano*, **5** (2011) 5627.
[8] Nie, Shu et al., *Phys. Rev. B*, ***85*** (2012) 205406



STM image of graphene on Pt(111) showing long range moirés patterns and atomic resolution (Bias Voltage = -35.7mV, Current set-point = 0.04nA).



STM image of graphene on Au(111) showing long dendritic islands at both sides of the steps. For this tip-state, graphene appears as a depression area (Bias Voltage = -12141.7mV, Current set-point = 4μA).