Ultralong natural graphene nanoribbons and their electrical conductivity

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Graphene is a 2D material with many possible applications in material science[1], nanomechanics[2] and nanoelectronics[3]. While high-yield production methods for grapheme sheets are a current hot research topic[4,5], the only practical way to obtain graphene flakes on insulating substrates is micromechanical cleavage[6]. Using this procedure it is relatively easy to obtain high-quality natural graphene flakes with well defined and clean edges oriented along the graphene crystallographic directions. However, nanoelectronic applications can benefit from an additional reduction of dimensionality from 2D flakes to 1D nanoribbons. So far, the only possible procedure to fabricate graphene nanoribbons (GNR) is using some kind lithography technique[7,8] but it is not obvious that the edges of these ribbons are cut following a crystallographic grapheme direction.

In this work, we present a new method for graphene flake deposition on surfaces based on silicone stamps. Using a combination of high resolution optical and atomic force microscopy (AFM) we characterize the topography of the flakes finding ultralong graphene nanoribbons with length greater than 30 µm and minimum width below 20 nm that are electrically characterized by conductance AFM. As the ribbons are consequence of the cleaving process (natural GNR) we expect clean edges along the crystallographic graphene directions, in contrast with those fabricated by lithography techniques.

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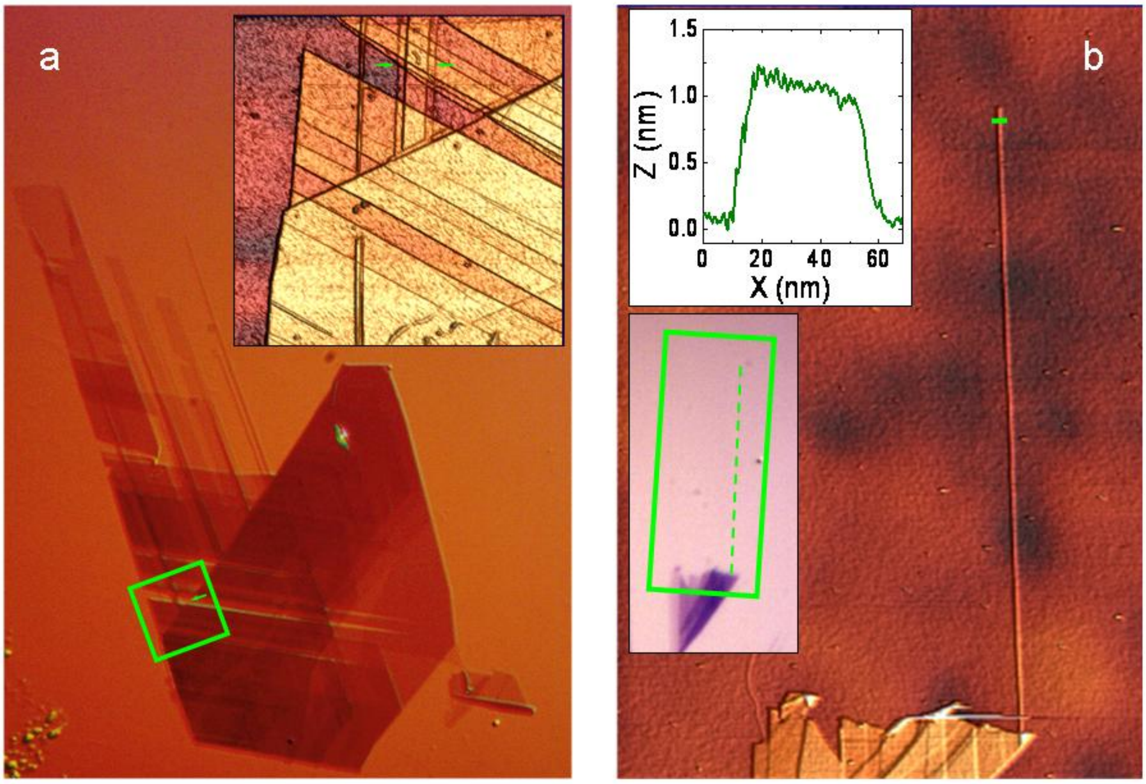

Fig 1. (a) Phase contrast optical microscopy image of a graphene flake and several ribbons following its crystallographic directions. The inset is a 10x10μm^2 AFM topography of the region enclosed by the square. The marked ribbon in the inset is 1.1μm wide and the thinner one on the left is 150nm wide. The former is also visible in the optical microscopy image (marked with an arrow) while the latter is hardly noticeable. As the optical microscope image shows, the sample surface is quite clean. (b) AFM topography of a 37nm wide ribbon emerging from a graphite flake. This ribbon has a length of ~24μm and a thickness ranging from 1 to 2nm. The upper inset is a profile taken along the green upper line showing the dimensions of the nanoribbon. The lower inset is a phase contrast optical microscopy image showing the mother flake. To guide the eye the position of the AFM image has been marked with a rectangle. Inside the rectangle a dashed line shows the position of the nanoribbon.