

Multitechnique Characterization of Atomically Precise Graphene Nanoribbons

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Abstract

Graphene nanoribbons (GNRs) – narrow stripes of graphene [1] – are predicted to be semiconductors with an electronic band gap that sensitively depends on the ribbon width [2]. The electronic properties of GNRs also depend strongly on the arrangement of the carbon atoms in the ribbon structure. For armchair GNRs (AGNRs) the band gap is inversely proportional to the ribbon width. On the other hand, zigzag GNRs (ZGNRs) are predicted to present spin polarized edges. Their gap opens thanks to an unusual antiferromagnetic coupling between the magnetic moments at opposite edge carbon atoms.

These versatile characteristics allow the design of GNR-based structures with widely tunable electronic properties, but require highest (i.e. atomic) structural precision. With our recently developed bottom-up approach the fabrication of atomically precise AGNRs [3] can be achieved using specifically designed precursor monomers. The monomers are sublimed in ultrahigh vacuum (UHV) and deposited onto metallic substrates such as Au or Ag. Substrate catalyzed dehalogenation of the monomers induces the formation of linear polymers that are subsequently cyclodehydrogenated to form the desired GNRs. With this approach, we have fabricated ultra-narrow GNRs and related graphene nanostructures for experimental investigations of their structural and electronic properties [3-10]. For the case of N=7 AGNRs (7-AGNRs), the electronic band gap and dispersion of the occupied electronic bands have been determined with high precision [9].

In this talk, we will show how different GNRs have been characterized following a multitechnique approach. The desired atomic precision obtained by this surface-assisted GNR fabrication method has been demonstrated by high-resolution Scanning Tunneling Microscopy (STM). Electronic properties like band dispersion and gap of GNRs have been determined by means of Scanning Tunneling Spectroscopy (STS), Angle Resolved Ultraviolet Photoemission Spectroscopy (ARUPS) and X-Ray Photoelectron Spectroscopy (XPS). Optical characterization of GNRs has been performed by means of in-situ Reflectance Difference Spectroscopy (RDS) [11]. Finally, we have characterized the vibrational properties of the GNRs by Raman spectroscopy, obtaining valuable information about the ribbon nanostructure.

References

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Figures

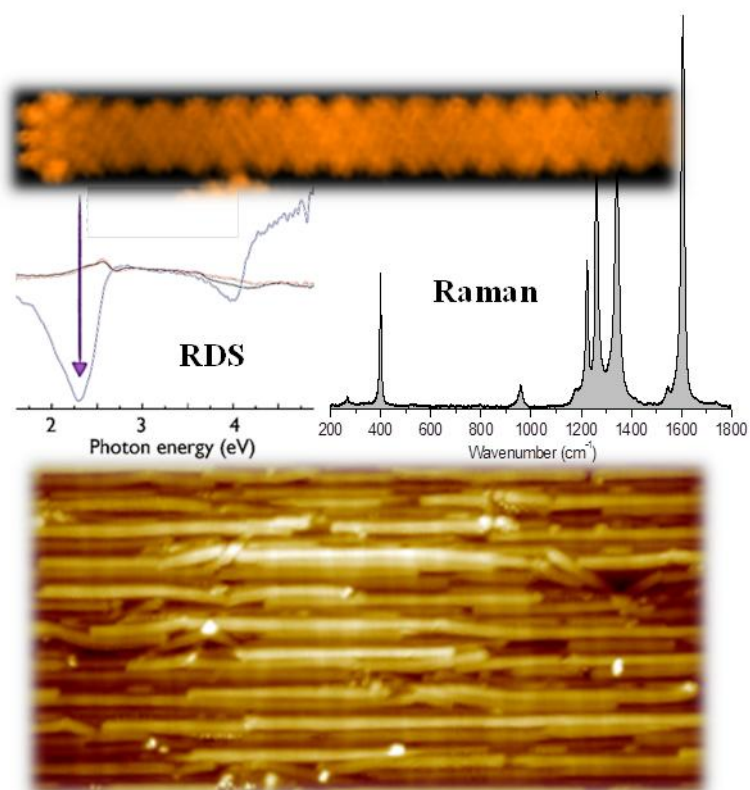


Figure. STM pictures of a 7-AGNR with one visible terminus (top) and aligned ribbons on the Au(788) surface (bottom). RDS (middle, left) reveals characteristic absorption features that are directly related to the electronic band structure of 7-AGNRs. Raman spectroscopy (middle, right) reveals the expected intensity distribution on G- and D-modes and the width-dependent characteristic radial breathing like mode (RBLM) at $\sim 400\text{ cm}^{-1}$.