Graphene nano-ribbon synthesis and STM imaging

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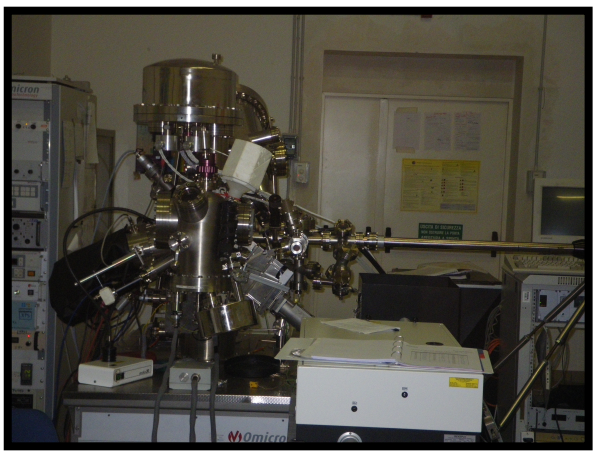
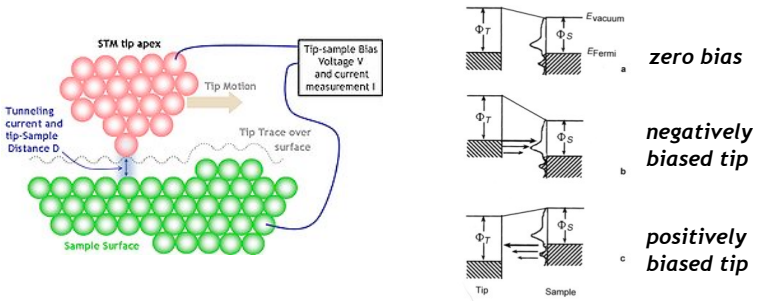
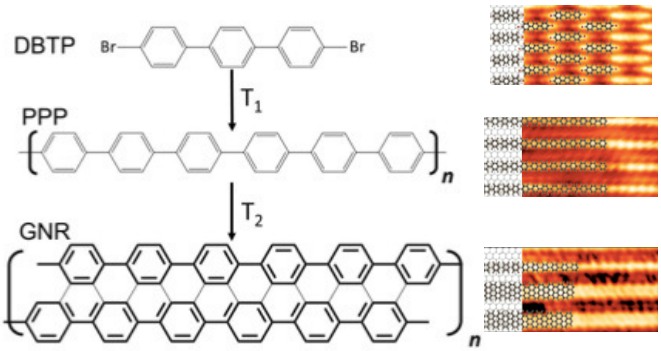


Experimental equipment of the research group

The experimental facilities of the Molecular Surface Science Laboratory of Padua including an Scanning Tunneling Microscope (STM), and a X-ray Photoelectron Spectroscopy device (XPS) allow to explore the on-surface bottom-up synthesis of 2D nano-structures. This year, the synthesis of graphene nanoribbons (GNRs) on gold surface (Au(111)) has been studied in depth.



Principles of Scanning Tunneling Microscopy

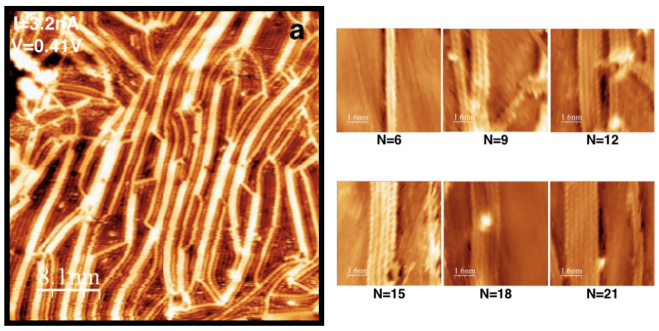


The three steps of the graphene nanoribbon synthesis

STM is a scanning probe microscopy technique. The measured physical quantity is the tunneling current flowing between the probing tip and the sample due to a quantum effect. Indeed, when two electrical conductors are close enough, electrons of one can fill the empty states of the other. If there is an electrical bias between the sample and the tip, the electrons flows only in one direction. Recording the vertical position needed to keep the tunneling current constant while scanning the sample enables nanoscale imaging.
Thanks to this technique, we can characterize the synthesis of our nanostructures.

GNR synthesis is in three main steps. After the self-assembly of 4,4"-dibromo-p-terphenyl precursors (DBTP) at room temperature on Au(111), a first annealing at 400K leads to the formation of polyparaphenylene wires. A second annealing at 650K leads to the lateral linking of the wires which produces graphene nanoribbons.
A large scale STM image shows the wide variety of the produced ribbons. We can expect to control their width with an appropriate protocole and so, their electronic properties.

High resolution STM image are needed in order to see the electronic density. We can compare this kind of image with numerical simulations in order to prove that the products actually are nanoribbons.



STM image of graphene nanoribbons synthesized on Au(111)

Left: numerical simulation, right: high resolution STM image

Conclusion : The successful elaboration of a new process to produce GNRs opened new fields of research for the Molecular Surface Science Laboratory. First, the protocole has to be optimized in order to well control the width of the GNRs. Then, other precursors has been tried to produce doped GNRs with different electronic properties. This year, precursors including nitrogen seem promising but it's very difficult to obtain the same level of order. Thus, stepped surfaces might lead to a better order. Some work has been made in this way.

Référence :
• Basagni, A., Sedona, F., Pignedoli, C. A., Cattelan, M., Nicolas, L., Casarin, M., & Sambi, M. (2015). Molecules–Oligomers–Nanowires–Graphene Nanoribbons: A Bottom-Up Stepwise On-Surface Covalent Synthesis Preserving Long-Range Order. Journal of the American Chemical Society, 137(5), 1802-1808.