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In-situ Raman spectroscopy and synthesis of one dimensional carbon nanostructures

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Abstract:

Semiconductor technology is one of the fields where the research using carbon nanostructured materials has a very promising scope of applications. However, to make their use possible in nanoelectronics it is necessary to have an accurate control of their structural properties. There are many ways of doing this. This PhD thesis focuses on the synthesis of one-dimensional carbon nanostructures, namely single-walled carbon nanotubes and carbyne, inside a protective nanoreactor, which is the hollow core of an outer single-walled carbon nanotube. To date, structures like these can be made with methods like chemical vapor deposition and other chemical methods. This PhD work focuses strongly on realizing an experimental technique to make this synthesis feasible on a localized spot combining the principles of CVD and focused laser annealing. The same laser is also used for in situ Raman spectroscopy. I implemented a vacuum system where the single-walled carbon nanotubes could be placed on top of a suitable substrate and then heated and used as chemical reactors while they were exposed to a hydrocarbon source to grow a new structure inside the hollow core. Coupling this setup to the Raman spectrometer was a key feature that allowed combining synthesis and spectroscopy for in situ studies of growth kinetics.

In this manner, it is possible to promote the synthesis and viabilize Raman measurements in-situ as a very promising solution for applications. Localized synthesis has been tried in other labs indeed. However, the advantage of this work relies on the starting material, which are nanotubes with a controlled diameter distribution and a known chirality. This provides an advantage to understand the material that grows inside and allows us going one step forward in the understanding of the properties of the inner tubes and linear carbon chains. This is a novel approach to make the chains and the work presented here paves the way for promising future work.

The first chapter is devoted to provide a thorough introduction to the field of carbon nanomaterials and the second chapter gives a background on their electronic and optical properties. The description of graphene has been taken into account in several sections for practical purposes. The third chapter provides in the first part an overview of the common synthesis methods. The second part focuses on the theoretical background of Raman Spectroscopy applied to carbon materials. Subsequently a description of in -situ methods is provided. The fourth, fifth and sixth chapters contain the results of the experiments with a thorough discussion. This also includes considerations regarding metallicity of the tubes, length of the chains and other aspects that are related to the state-of-the-art in the field. Finally, I have included a chapter providing brief conclusions and a perspective of where to go with these results and how to inspire new experiments.