

The graphene era: One-atom-thick electronics

The wonder material, as some like to address graphene, has drawn an extensive interest for being the strongest, most flexible and first one-atom-thick structure to be found. The unexpected discovery in 2004 of this structure, made of carbon atoms, laid the groundwork for the broad spectrum of new slim materials yet to come. The combination of graphene with these highly thin materials (2D-materials) allows not only to study graphene's remarkable properties, but also to create novel microscopic devices out of it. Because of its unique nature, graphene is steadily working its way into today's silicon dominated electronic industry.

It was not long ago when transistors made of silicon revolutionized our computers and phones. These small devices, presently of the size of ten to a few nanometers ($1 \text{ nm} = 0.0000000001$ meters), are able to act as a switch when a voltage is applied. The larger the number of "electrical switches" the faster our computers or phones will work. The discovery of graphene and its great conducting properties has led scientists to try and integrate it in silicon-based transistors by combining it with other new 2D-materials.

It seems rather fictional to be dealing with atomically thin layers of materials. However, graphene is a material that comes from the very same graphite that our pencils are made of. Imagine a stack of post-its representing bulk graphite; then, each post-it would correspond to precisely one graphene layer.

Surprisingly, isolating a thin layer of graphene is as simple as placing scotch tape on top of bulk graphite and peeling away graphene layers as the tape is lifted. In the same way a post-it is placed onto a paper, once isolated, graphene can be placed onto a substrate and then observed through a microscope. This entire process is called exfoliation and it is an important part of this thesis, because it can be repeated with a plethora of other materials to create unique 2D-material devices.

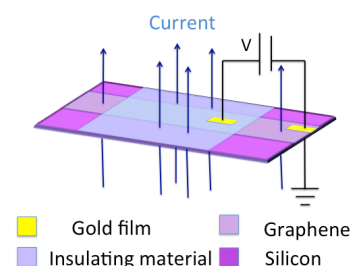


Figure 1. Device structure

The work in this project shows how one graphene layer, sandwiched between a silicon substrate and a thin insulating material (e.g. boron nitride), can be a prototype for a transistor if a bias is applied (Fig.1). For this purpose, a very thin film of metal (gold) must be evaporated onto the device, to function as an electrical contact. Theoretically, current should not be able to flow due to the insulating material. However, in the realm of quantum mechanics (i.e. at the atomic scale), some of the current is able to tunnel through the insulator. Thus, this special type of transistors bears the name of 'tunneling field effect transistor' and the current extracted through it will give intrinsic information about graphene, such as its conductive properties. Before tunneling transistors are realizable in the market, the properties of graphene can be studied with these actual devices. Understanding them is of utter importance for future applications of graphene in not just electronics, but also areas like solar cells technology or even medicine.

Supervision: **Tomas Brage & Jairo Velasco** (UCSC)

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Division of Solid State, Department of Physics, Lund University

Department of Solid State Physics, University of California, Santa Cruz (UCSC)

*Subject of the work: see syllabus