PhD Proposal 2017

School: Ecole centrale de Lyon	
Laboratory: Institut des nanotechnologies de Lyon (INL)	**Web site:** inl.cnrs.fr
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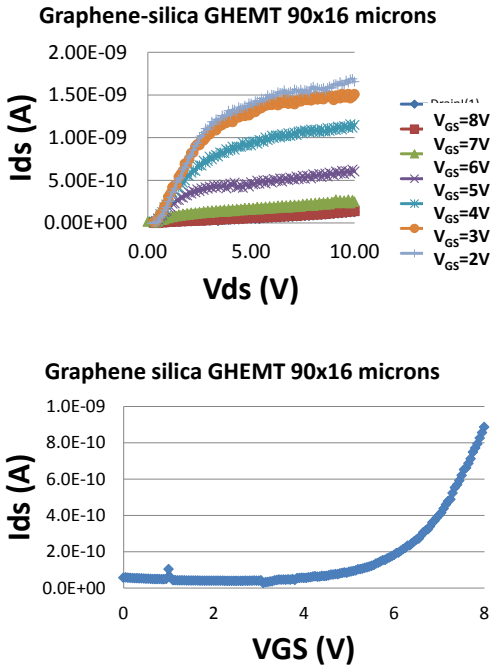
Collaboration with other partner during this PhD: Yes **In France:** Laboratoire AMPERE, INSA de Lyon, Villeurbanne	 **In China:** Electronic Materials Research Laboratory, Key Laboratory of the Ministry of Education & International Center for Dielectric Research Electronic and Information School Xi'an Jiaotong University

Title: Realization of a single layer graphene field effect transistor
Scientific field: nanotechnologies
Key words: graphene, transistor, nanoelectronic

Details for the subject:

Background, Context:

Graphene is a semiconductor with zero band gap, linear energy dispersion, and linear density of electronic states. One of its most important properties is a strong electric field effect which leads to an electrostatically tunable carrier density in the range of $n < 1.\ 10^{14}$ cm^{-2}. Together with high carrier mobility for both electrons and holes (as high as 10000 $cm^2/V.s$ at room temperature), graphene is considered as a possible material for a future high-speed field effect transistor (FET). On another hand, this material is also used for low noise electrodes in the field of electrochemistry for applications in medicine, environment and industry. A study toward graphene utilization for the transistor channel has already been demonstrated by our group [1, 2]. A normally-off switch has been obtained with source and drain contacts made on p-type SiC mesa-etched layers up to the SiC n-type layer where the graphene layer has been created. A SiO_2 functional oxide layer has been deposited on the graphene and patterned for the gate metal contact. This transistor structure allowing drain current modulation with gate voltage, relatively high lateral on-state current is obtained up to 0.1 A/mm (4 mA for a 40µm channel width). The switching on seems to not be due to the p/n junction between the p+-source and the n-layer bellow the gate, this junction being polarized in reverse bias and thus the channel conduction is due to the presence of the graphene layer. $I_{DS}(V_{DS},V_{GS})$ current-voltage curves are presented in the figure below for a 90 µm width and 16 µm graphene channel length transistor.



Current-voltage curves for a 90 µm (width) and 16 µm (length) Graphene FET.

Research subject, work plan:

After the first proof of concept, several studies are needed to optimize the Graphene FET:

- Optimize and characterize the fabrication of mono- and poly-layers of epitaxial graphene on SiC.
- Determine the best choices for the device nanostructuration (device sizes, etching, metallic contact, etc.) and then fabricate and characterize a field effect transistor.
- Replace the gate silica by other metal oxides: high-k and ferroelectric in order to realize the first Graphene FET with non-volatile ferroelectric gate.
- Study the graphene surface functionalization in order to fabricate biosensors, since the SiC is biocompatible.

This work will be realized in close relationship with Dr NIU Gang at Xi'an Jiaotong University (China) for the graphene and device characterizations [3].

References:

[1] J. Pezard , J. Lhuillier, Z. El-Friakh, V. Soulière, B. Vilquin, P. Rojo Romeo, M. Lazar, "Realization and characterization of Graphene on 4H-SiC for Tera-Hertz transistors", Materials Science Forum Vols 821-823 (2015) pp 941-944.

[2] J. Pezard , M. Lazar, N. Haddour, C. Botella, P. Roy, J.-B. Brubach, B. Vilquin, P. Rojo Romeo, F. Buret, "Realization of a graphene gate field effect transistor for electrochemical detection and biosensors", *in press*, Thin Solid Films (2016).

[3] Niu Gang, Capellini Giovanni, Lupina Grzegorz, Niermann Tore, Salvalaglio Marco Marzegalli Anna, Schubert, Markus Andreas, Zaumseil Peter, Krause Hans-Michael, Skibitzki Oliver, Lehmann Michael, Montalenti Francesco, Xie Ya-Hong, Schroeder Thomas, "Photodetection in Hybrid Single-Layer Graphene/Fully Coherent Germanium Island Nanostructures Selectively Grown on Silicon Nanotip Patterns", ACS Applied Materials and Interfaces 8, 2017-2026 (2016).