Atomically precise graphene nanoribbons: the road towards device applications

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Graphene nanoribbons (GNRs) show exciting properties deriving from electron confinement and related band gap tunability[1]. The ability to tune GNRs' electronic and magnetic properties at the single atom level makes them an ideal platform for a wide range of device applications, from classical transistors to spintronics. In this talk, I will give an overview of the necessary steps to bring GNRs from ultra-high vacuum (UHV) to device integration, focusing on the synthesis, characterization, and transport measurements of atomically precise graphene nanoribbons. After the UHV bottom-up growth, GNRs are transferred using different transfer methods based on wet[2] and semi-dry/dry-transfer methods. Those processes allow the characterization of GNRs fingerprint modes via Raman spectroscopy[3] as well as the characterization of their electronic properties on decoupled substrates such as quasi-free-standing graphene. Next, I will show our progress in integrating different armchair GNRs (5-, 9-, 17-AGNRs) into field-effect transistors with different gate and contact configurations. We demonstrated the highest I_{on} current GNR-FET device to date by using a double-gate configuration[4]. 9-AGNR-FETs showed I_{on} currents up to 12µA and I_{on}/I_{off} up to 10^5. By integrating 9-AGNRs into FET devices using graphene and carbon nanotubes[5] as electrodes we also demonstrated tunable multi-gate devices showing quantum dot behavior with rich Coulomb diamond patterns, Figure 1.

References

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[4] Z. Mutlu *et al.*, IEEE International Electron Devices Meeting (IEDM), 37.4. 1-37.4. 4, 2021
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Figures

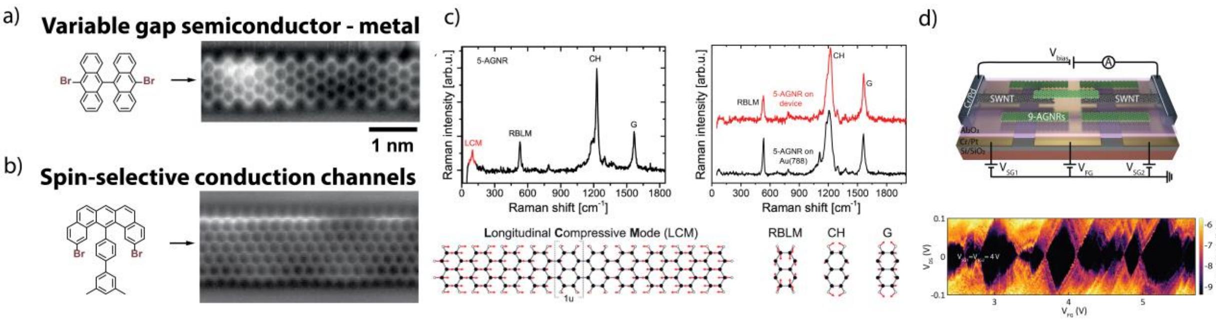

Figure 1: a) and b) *precursor monomers for GNRs with different edge topology and correspondent noncontact atomic force microscopy (nc-AFM) images, c) Raman spectrum of 5-AGNRs with assignment of the most prominent peaks on Au (111) and on the device substrate after transfer; atomic displacement profiles obtained from DFT calculations of 5-AGNRs, d)* Schematic of the device, using CNT as electrodes, including the measurement circuit; stability diagram showing single-electron charging behaviour.