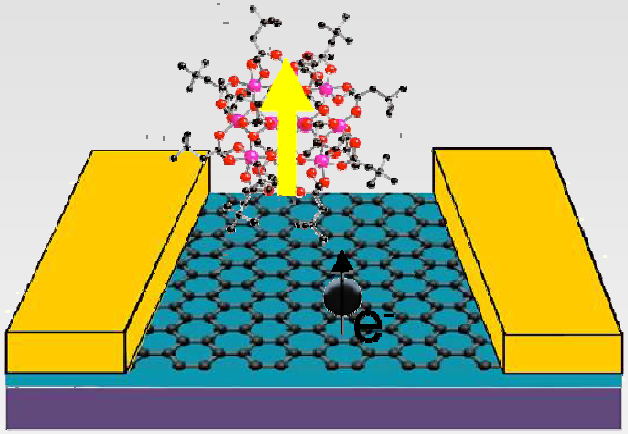
Hybrid Graphene - Molecular Magnet Devices for Spintronics



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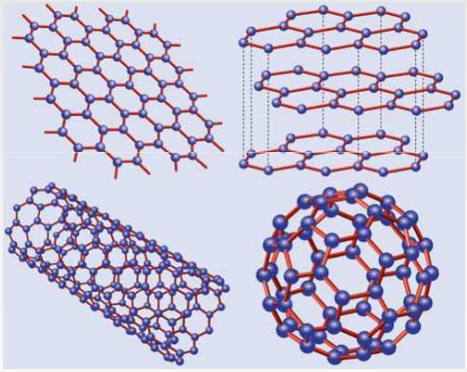
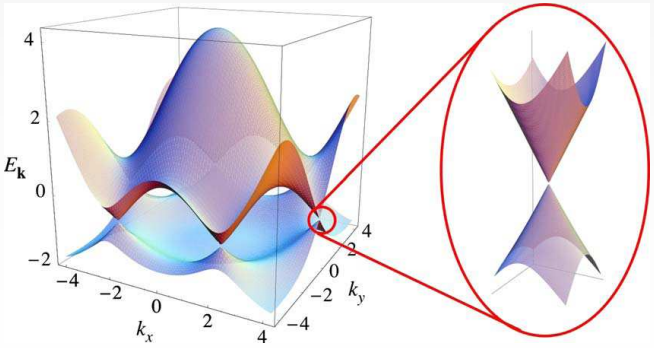
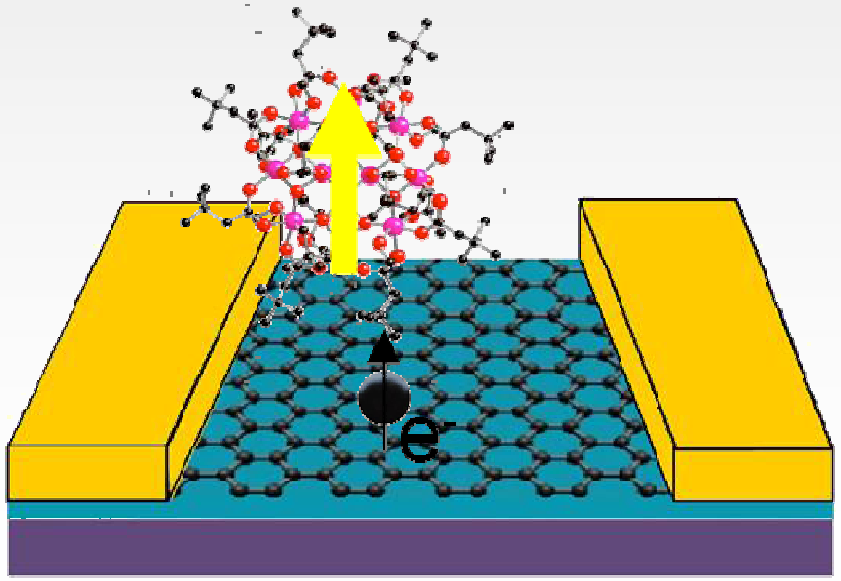
Molecular Spintronic with Graphene

Idea: Study and control **charge** and **spin** in devices where **graphene** is decorated by nano-magnets (molecular magnets, nanoparticles etc…)





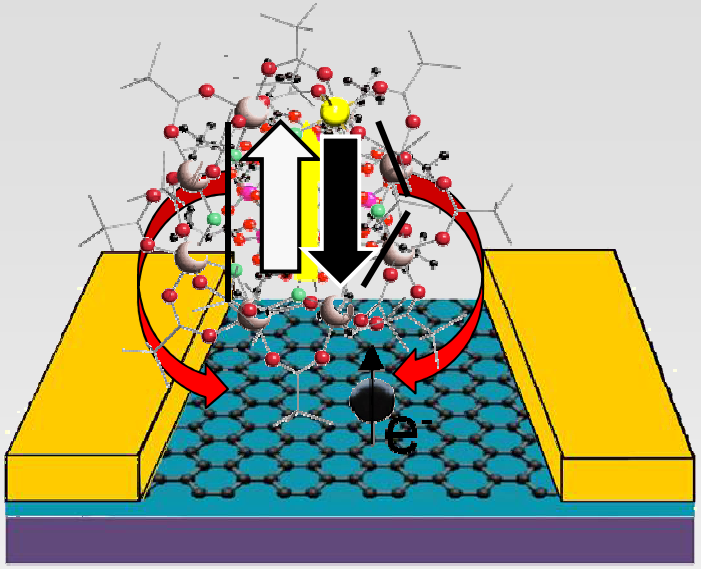
Geim et al. *Nat Mat* 2007
Castro Neto et al *Rev Mod Phys* 2009



Motivation : Graphene is a "naked" 2DEG

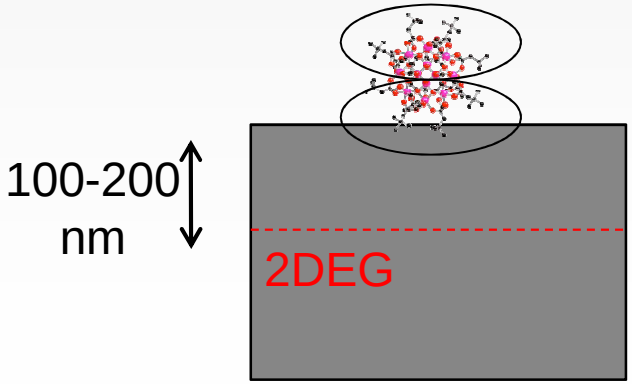
nano-Magnetometry

Detection possible down to
Single Molecules

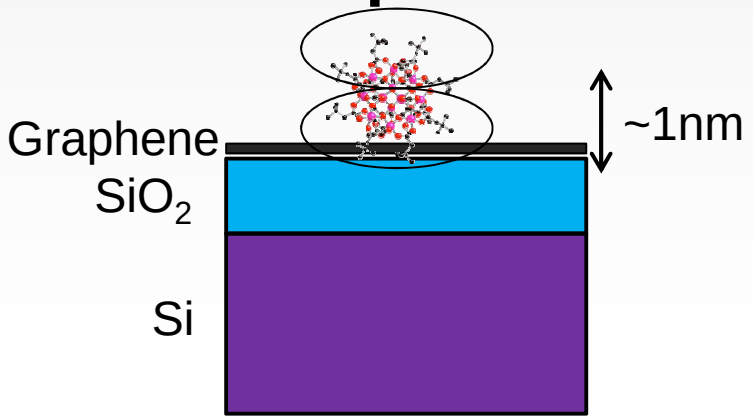


Example: Magnetic flux coupling

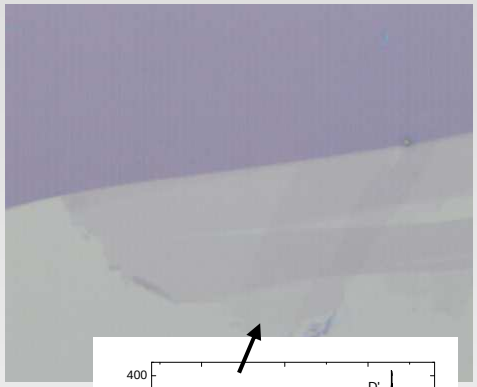
Traditional 2DEG

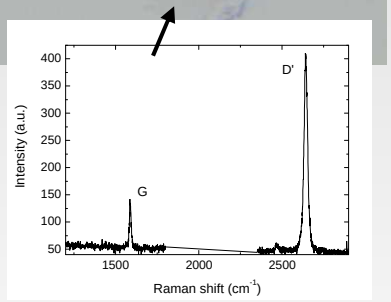


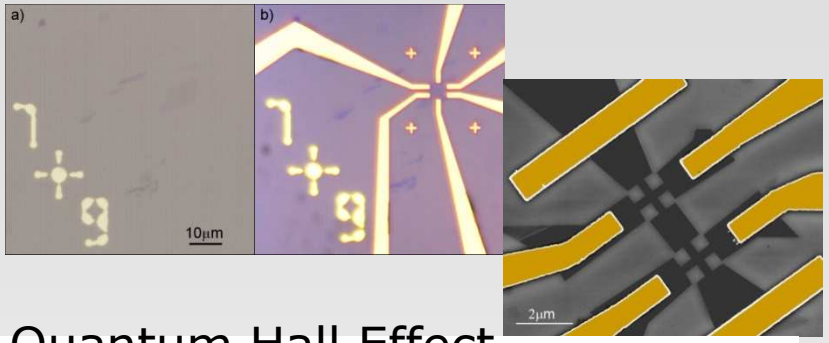
Graphene



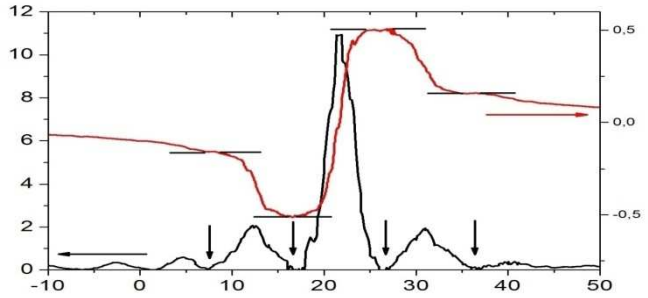
Devices Fabrication







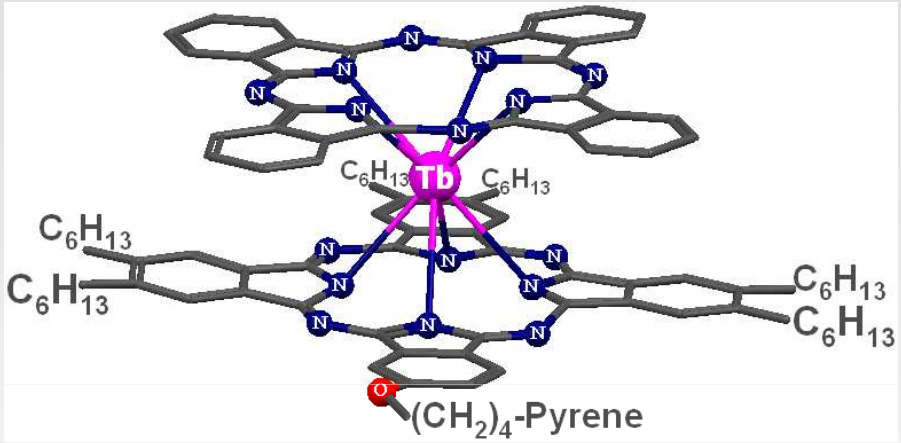
Quantum Hall Effect

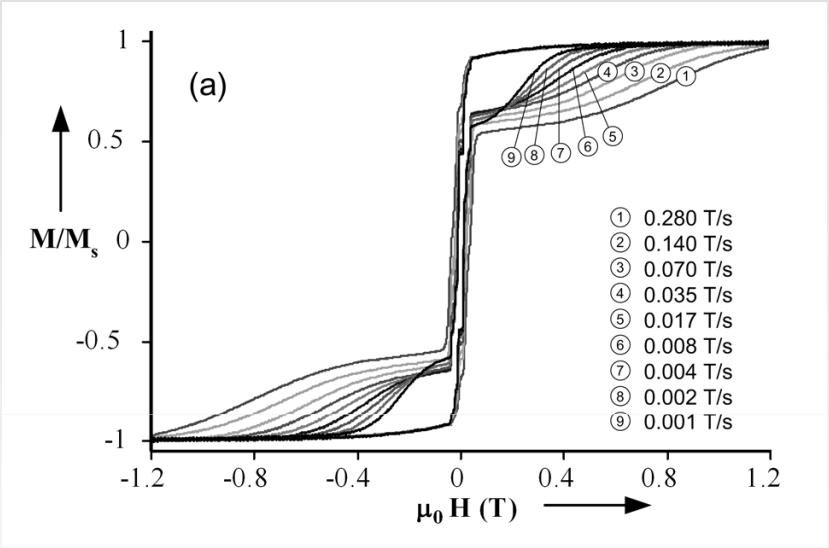


- Graphene obtained by the Scotch-tape method
- Characterization by micro-Raman spectroscopy
- Electron Beam Lithography to define contacts and to etch devices
- Devices of good quality (observation of Quantum Hall effect)

Molecule Grafting: Tb-Double Decker

(group of Mario Ruben, KIT, Germany)





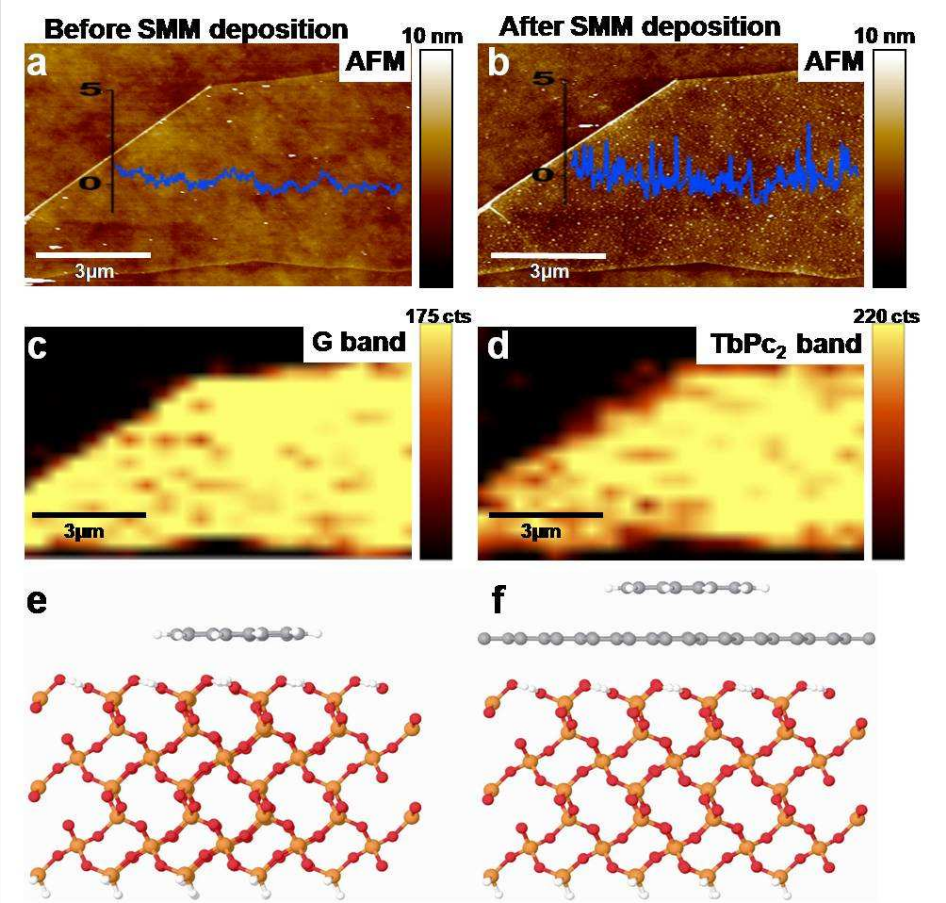
N. Ishikawa et al, *Angew Chem Int Ed* **44**, 2931 (2005)

- Known magnetic behavior
- Can we control the grafting?
- Is the molecule stable on surface?

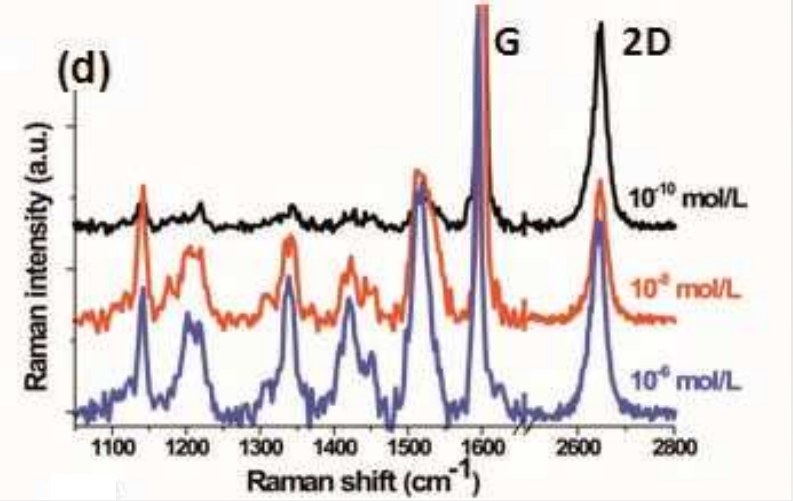
Molecules dispersed in DCM

Deposition: dropcasting after device fabrication

Deposition study



Study at different concentrations

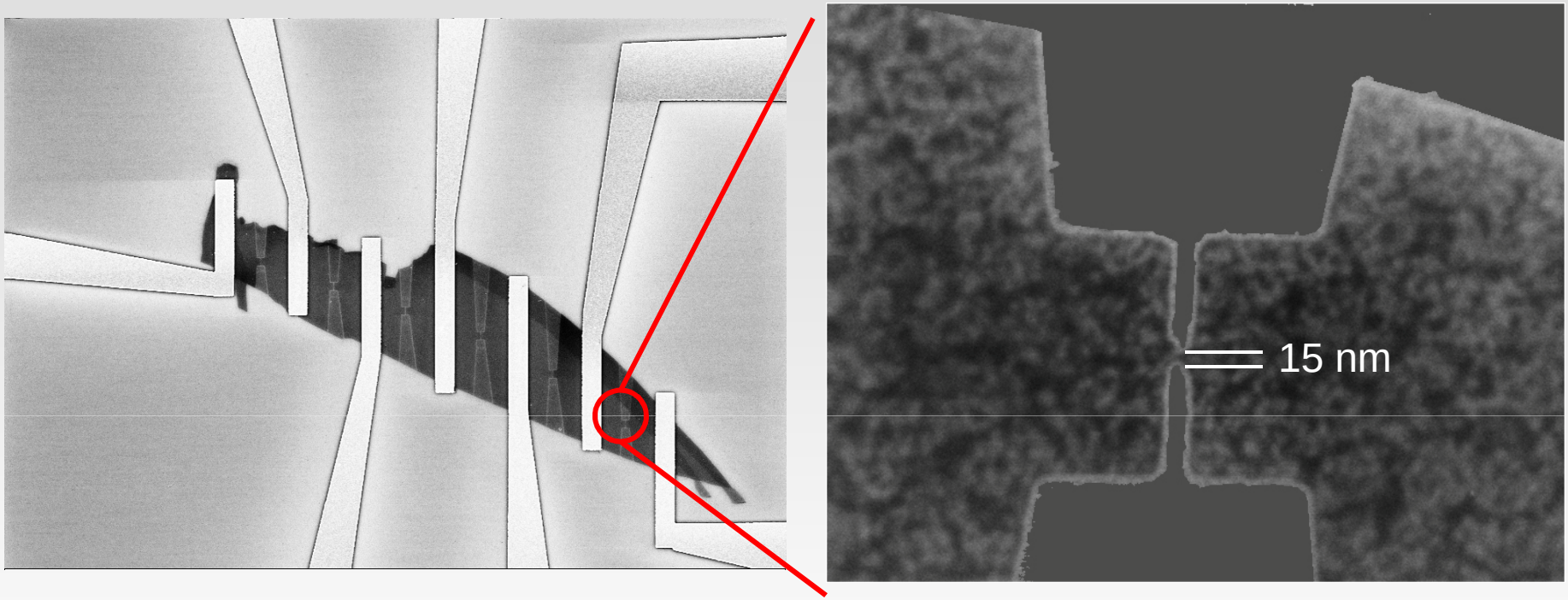


All the peaks of the molecule are always present

- Grafting is selective on graphene with respect to SiO_2
- Molecules are still intact even at low concentration (no cluster)

M. Lopes, A. Candini et al., ACS Nano 4, 7531-7537 (2010)

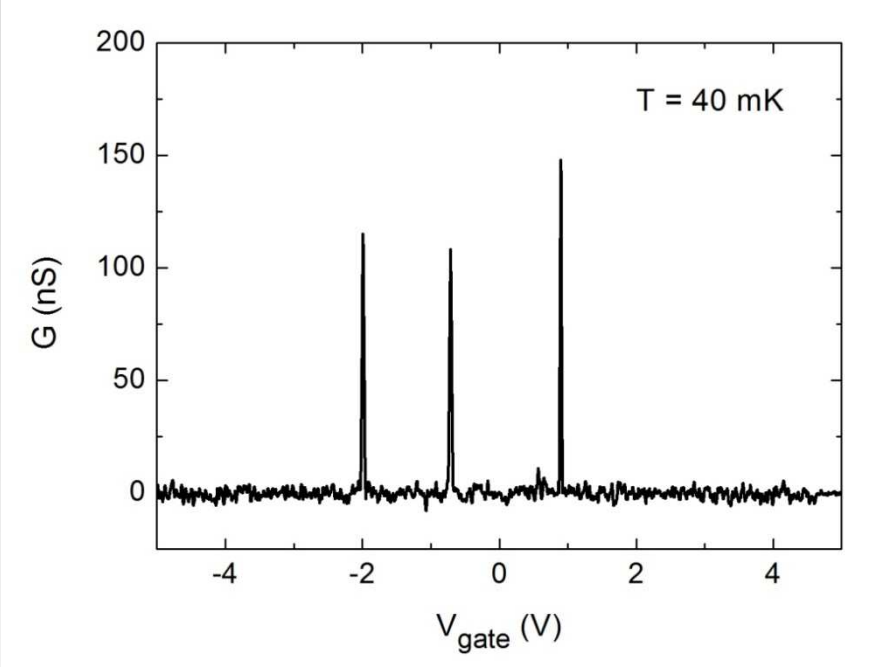
Device: nanoconstriction (QPC)

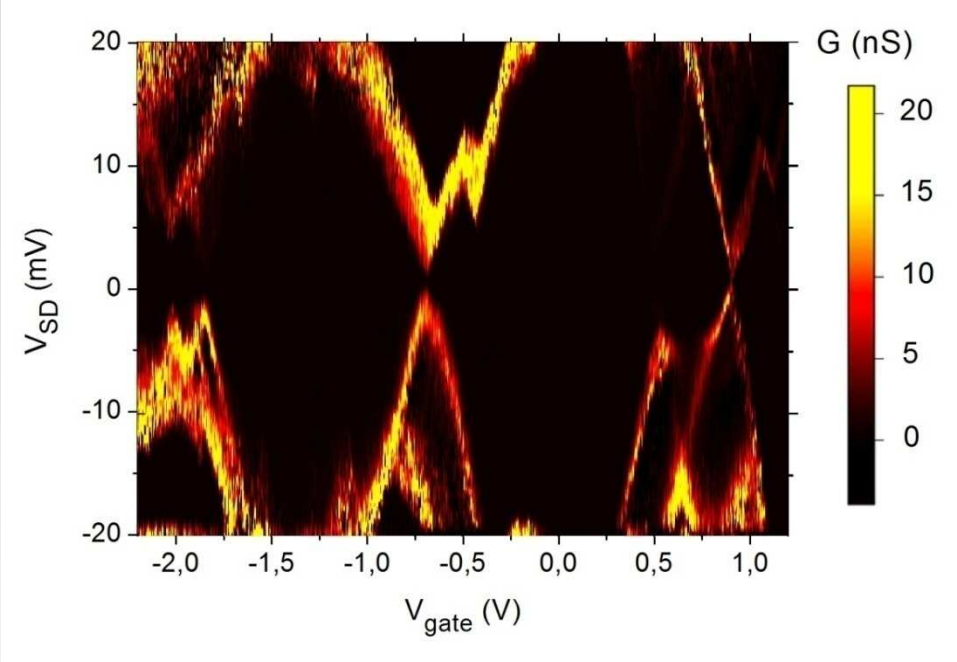


Idea: reduce graphene to a 0-D system to couple to individual molecules

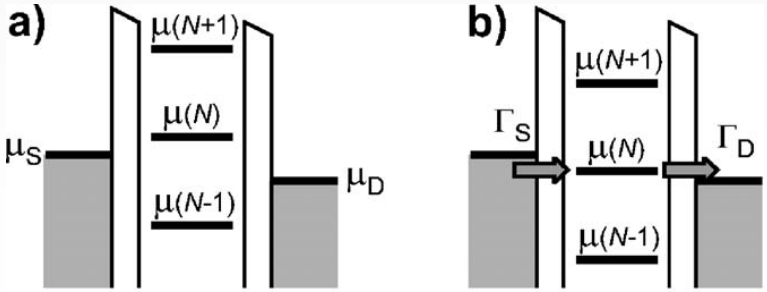
Nanometer-size Device: sensitivity to few (single) nano-objects

Transport in a small (~15 nm) nanoconstriction

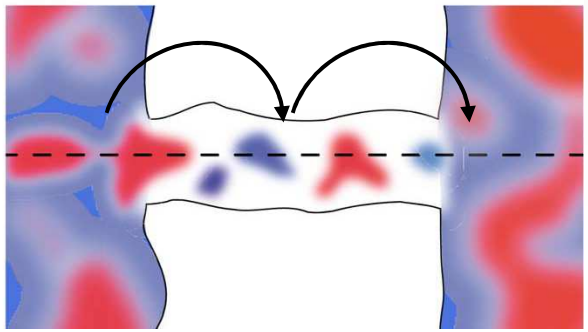




Coulomb - blockade behavior
(Quantum Dot)



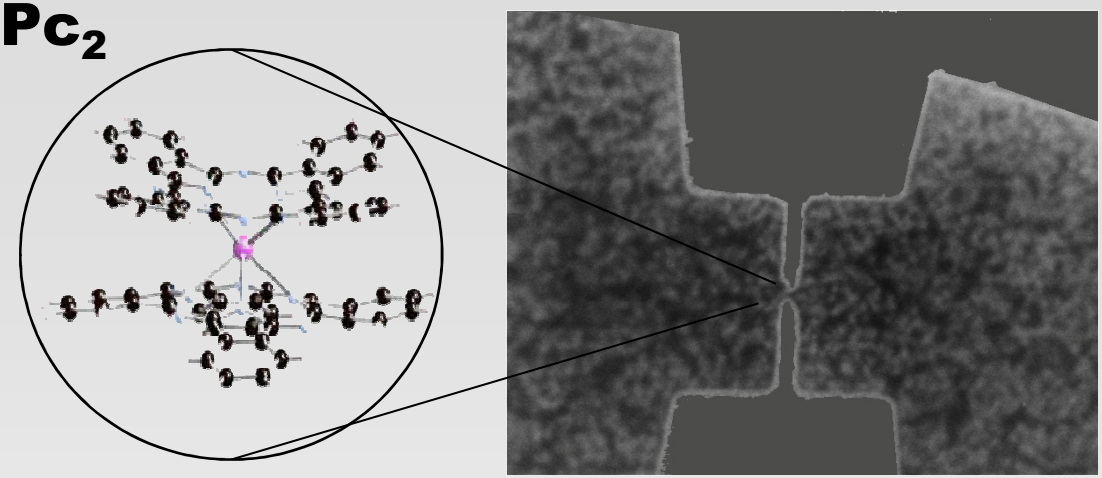
Transport:
tunneling between
conductive regions

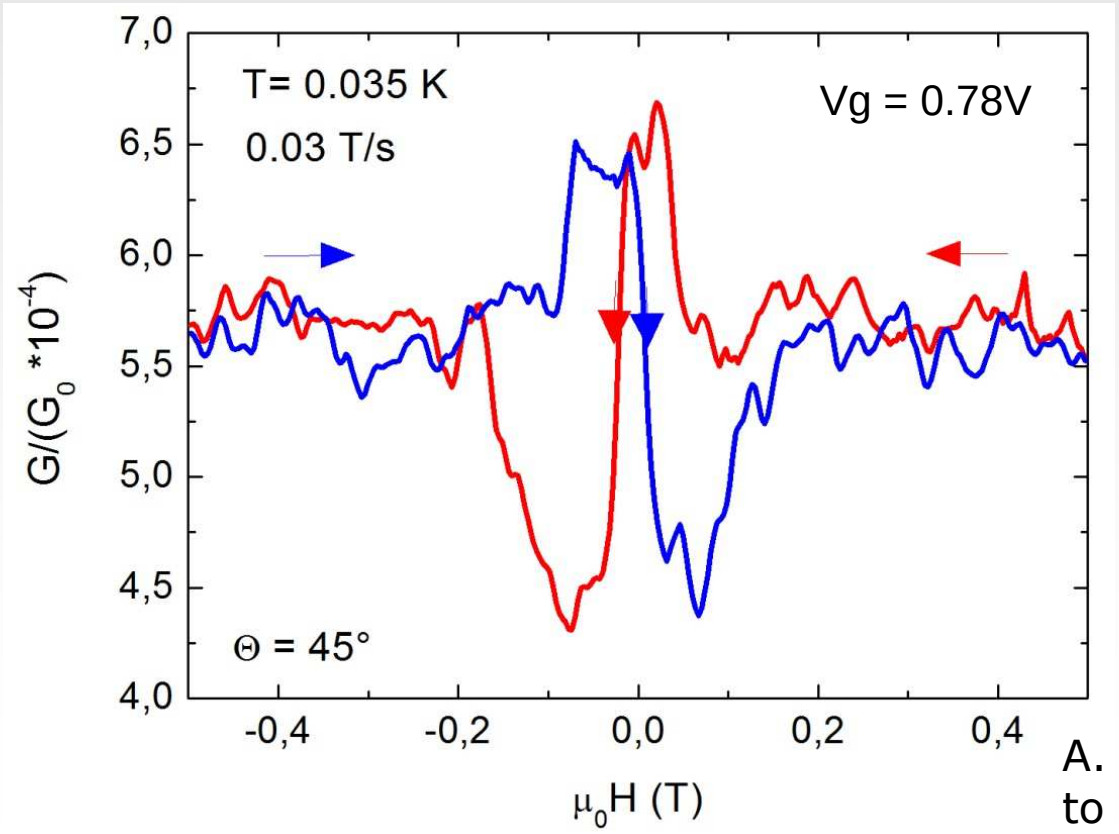


Gallagher, PRB 81, 115409 (2010)

Graphene QPC with Tb-Pc_2

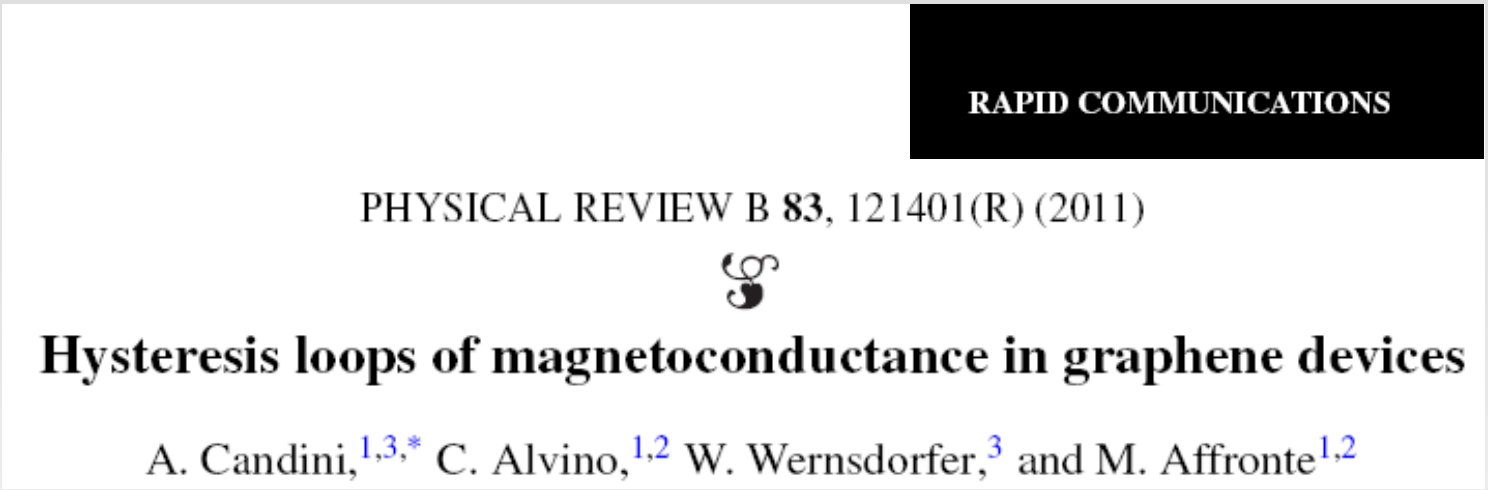
Estimation: ~10 molecules





A. Candini et al, to appear in Nano Letters (2011)

Attention: What happens without meolcules ?



RAPID COMMUNICATIONS

PHYSICAL REVIEW B **83**, 121401(R) (2011)

Hysteresis loops of magnetoconductance in graphene devices

A. Candini,[1,3,*] C. Alvino,[1,2] W. Wernsdorfer,[3] and M. Affronte[1,2]

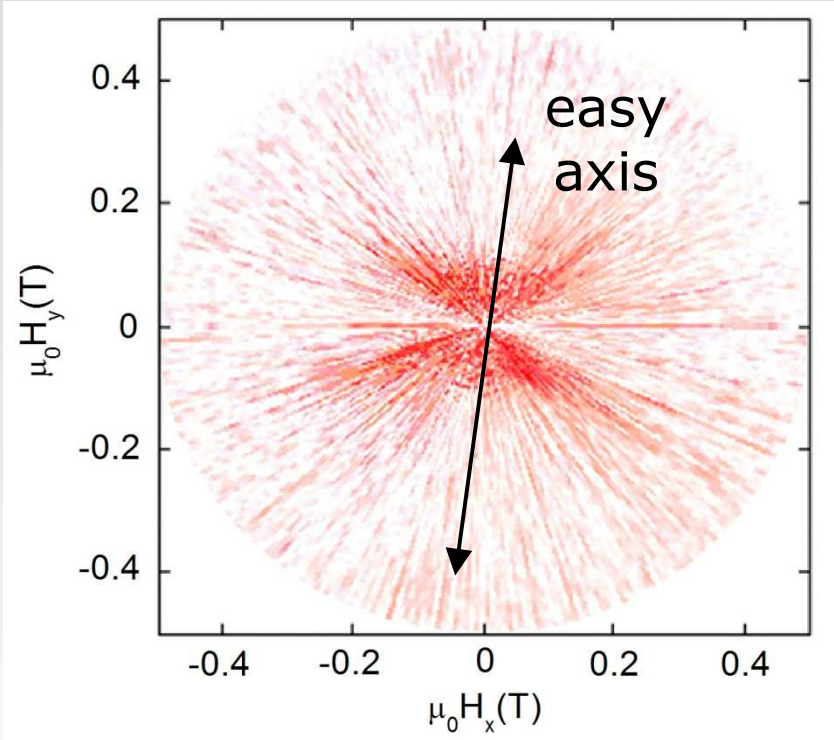
- Small (para)magnetic signal found also in “empty” Devices

- Presence of defects?

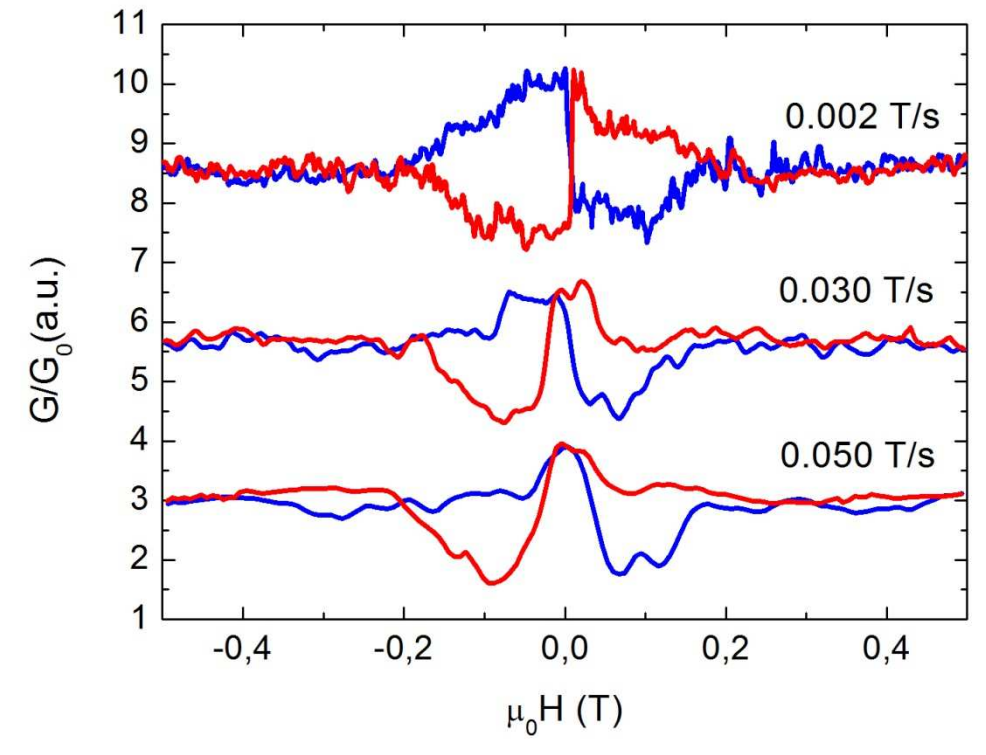
- According with other experimental results

Check for the molecule characteristics

Angular dependance



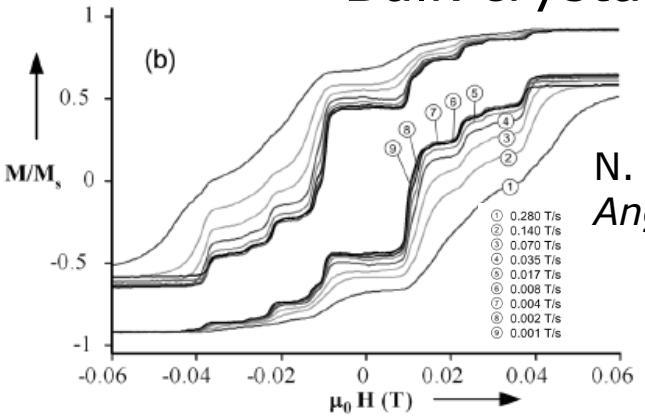
Field sweep rate dependance



Axial anisotropy
(expected for $TbPc_2$)

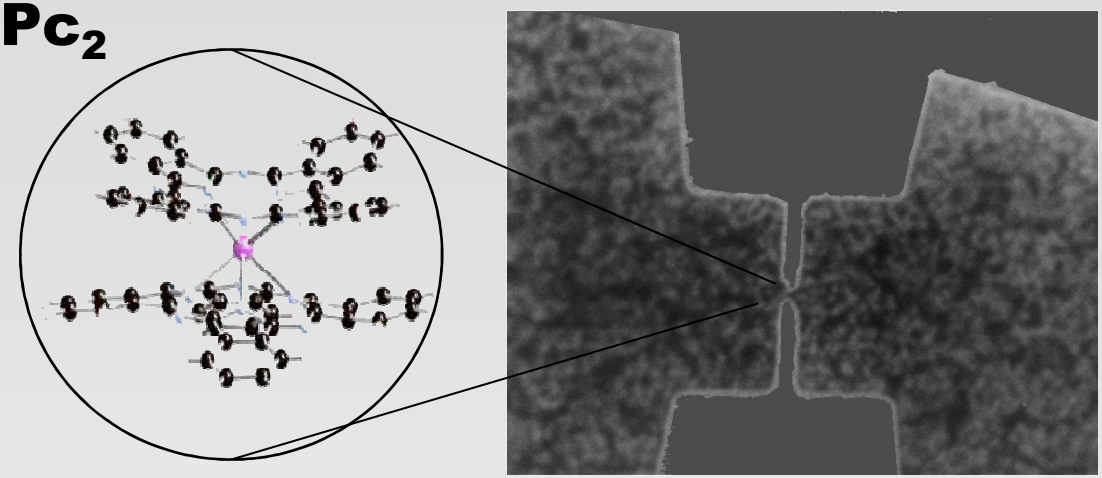
A. Candini et al,
to appear in
Nano Letters (2011)

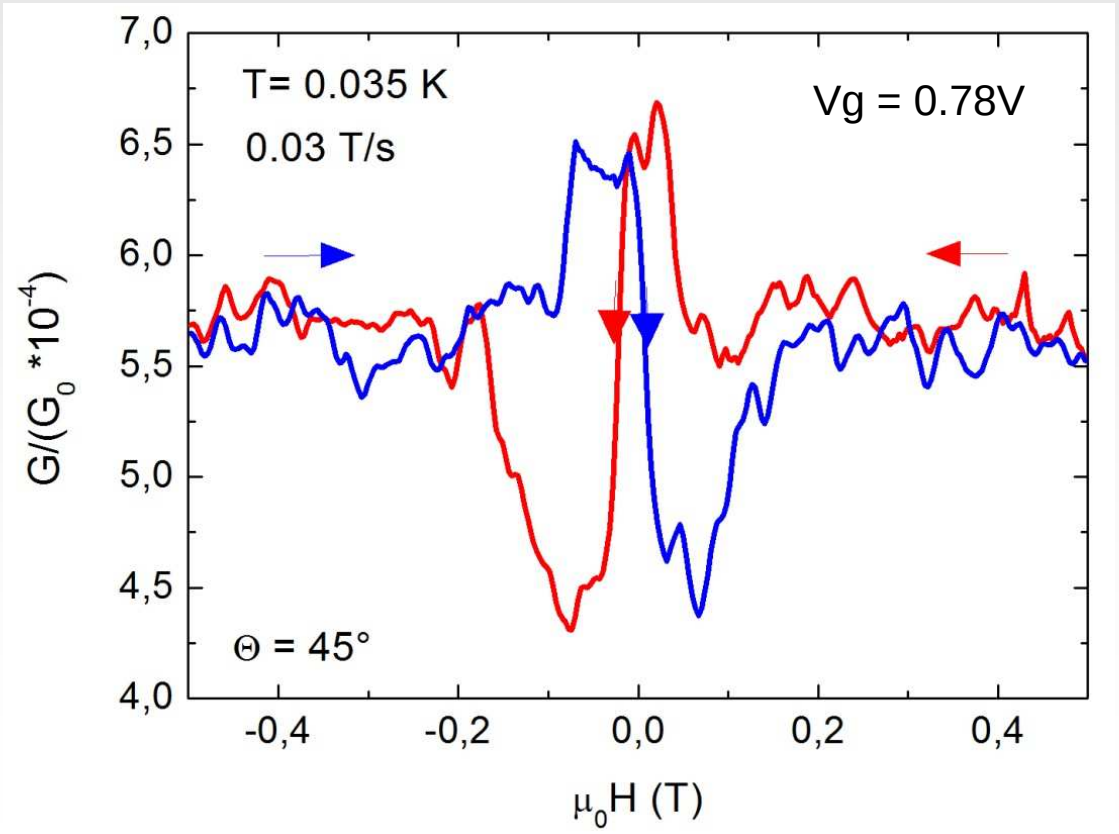
Bulk crystals



N. Ishikawa et al,
Angew Chem Int Ed **44**, 2931 (2005)

Graphene QPC with Tb-Pc_2





A. Candini et al,
to appear in
Nano Letters (2011)

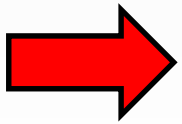
Conclusions

- Grafting of SMMs on Graphene:

  Selective
  Molecules are still intact
  Graphene is not damaged

- Realization of a **novel** nano-**device**:

  Spin-Valve behaviour *without* ferromagnetic contacts



Detection of SMM spin reversal

Thanks to

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