XIII ème colloque Louis Néel

Ultrathin epitaxial cobalt films on graphene: perpendicular magnetic anisotropy

C. Vo-Van[1], Z. Kassir-Bodon[1], H. Yang[2], J. Coraux[1], J. Vogel[1], S. Pizzini[1], P. Bayle-Guillemaud[3], M. Chshiev[2], L. Ranno[1], V. Santonacci[1], P. David[1], V. Salvador[3], and O. Fruchart[1].

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[2]SPINTEC, CEA/CNRS/UJF/G-INP, INAC
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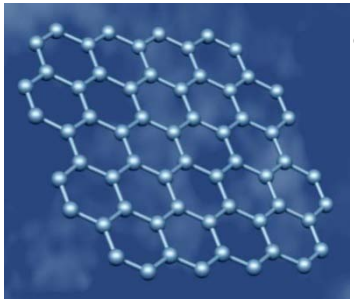
- Growth & structure of ultrathin Co films on graphene
- Perpendicular magnetic anisotropy
- Low coercive field
- Weak domain wall pinning

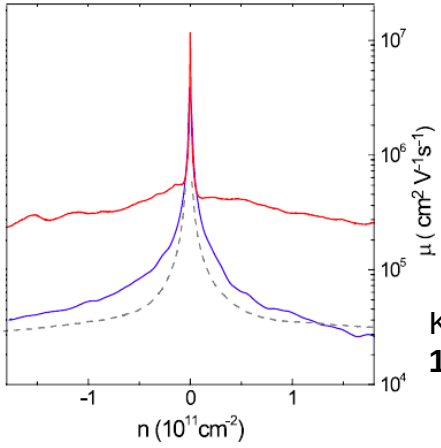
Chi Vo-Van, Zoukaa Kassir-Bodon, Hongxin Yang, Johann Coraux, Jan Vogel, Stefania Pizzini, Pascale Bayle-Guillemaud, Mairbek Chshiev, Laurent Ranno, Valérie Santonacci, Philippe David, Violaine Salvador, and Olivier Fruchart, *submitted*.

Graphene in spintronics



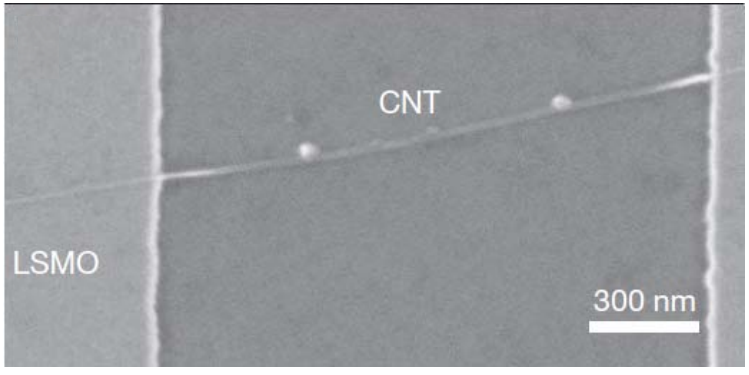
- Weak spin-orbit coupling
- Low hyperfine interaction
- High electron mobility

➔ Long-range spin transport

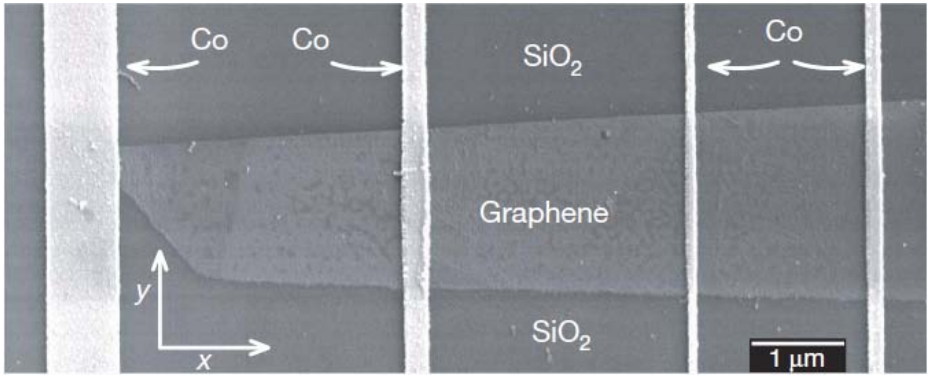


High μ at 300K and noticeable charge doping

K. Bolotin,et al., Sol. State Comm. **146**, 351 (2008).



L. E. Hueso, et al., Nature **445**, 410 (2007).



N. Tombros, et al., Nature **448**, 571 (2007).

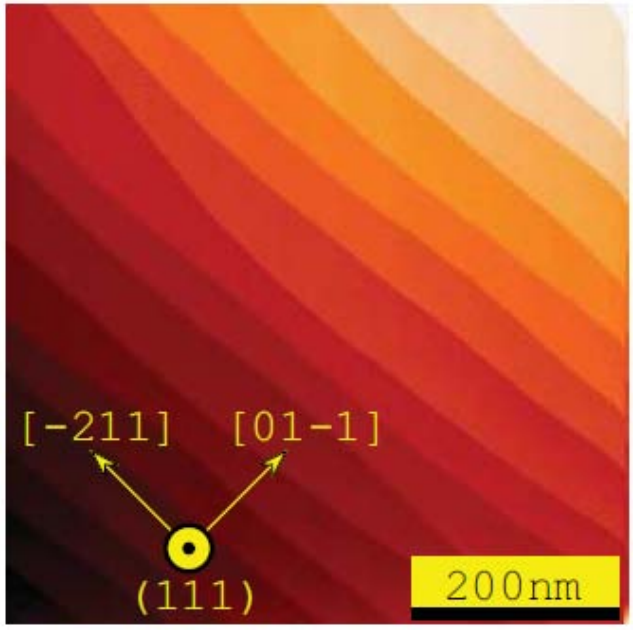
Graphene➔ integrability and patterning (on-wafer sample)

High quality of Ir (111) on sapphire

Pulsed-Laser Deposition under UHV

Deposition: 430ºC; Annealing: 850ºC

STM

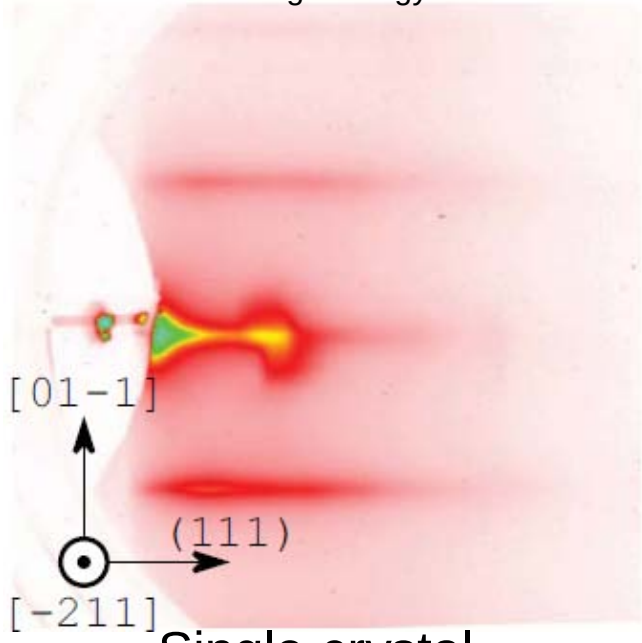


Thickness: 9nm

Atomic steps

C. Vo-Van et al., in preparation

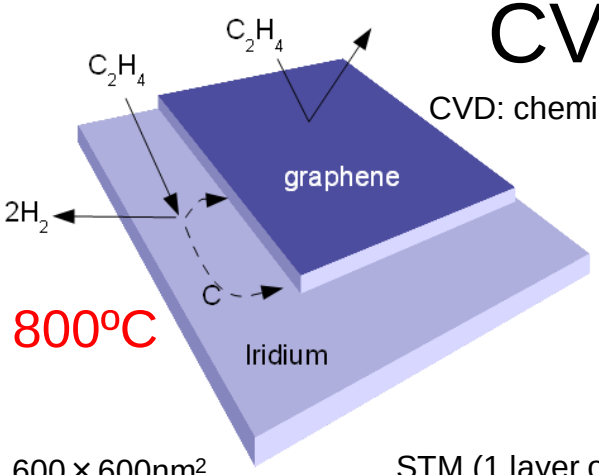
RHEED: Reflection high energy electron diffraction



Single crystal

Ir (111)-9nm
Sapphire (0001)

CVD of Graphene on Ir

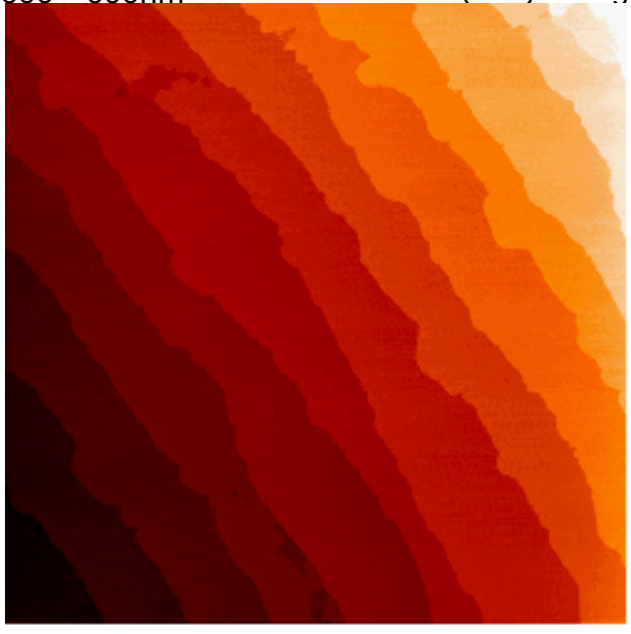


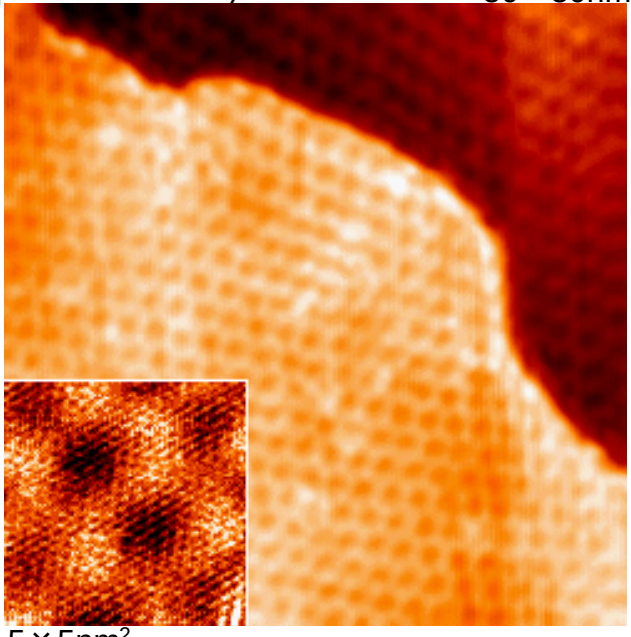
CVD: chemical vapor deposition

- Single layer (self-limiting)
- ~ full coverage
- Comparable to results on single crystal

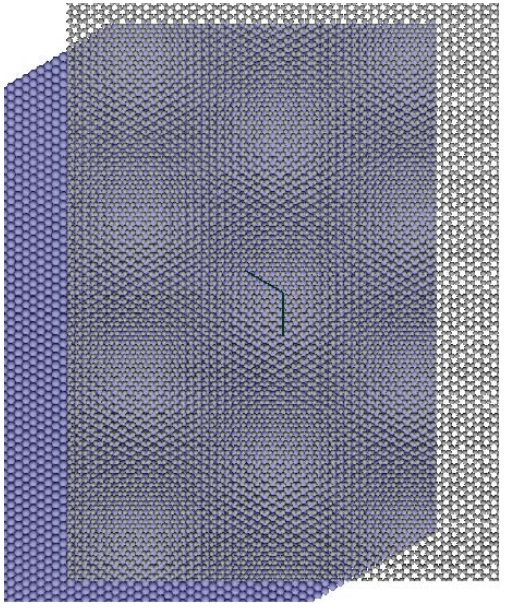
J. Coraux, et al., Nano Lett. **8**(2), 565 (2008).

$600 \times 600 nm^2$ STM (1 layer of graphene on Ir-9nm) $50 \times 50 nm^2$





$5 \times 5 nm^2$



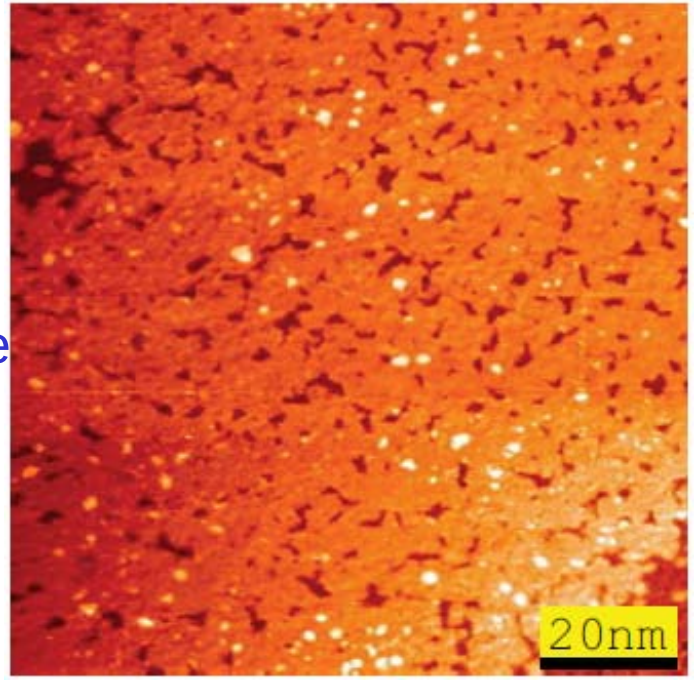
Ultrathin Co on graphene

Pulsed-Laser Deposition

- Layer-by-layer growth up to 1.5nm

STM
(thickness 0.8nm)

Growth at room temperature



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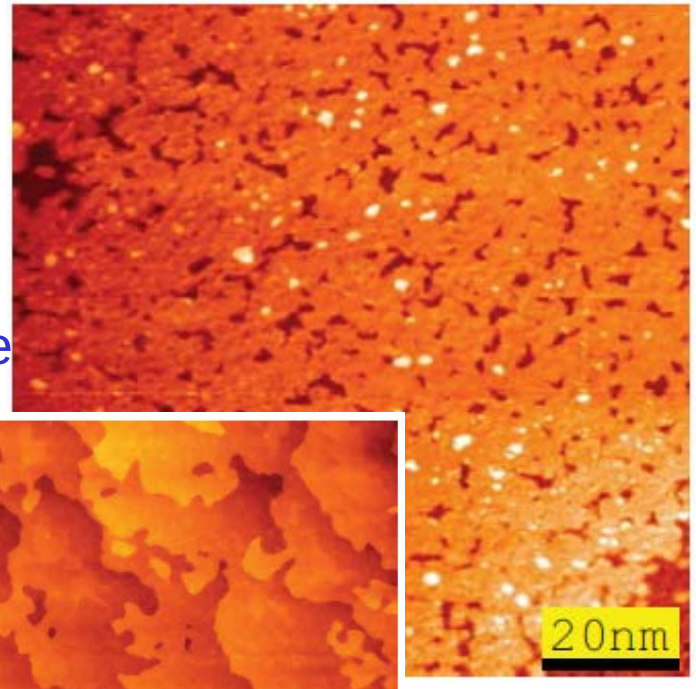
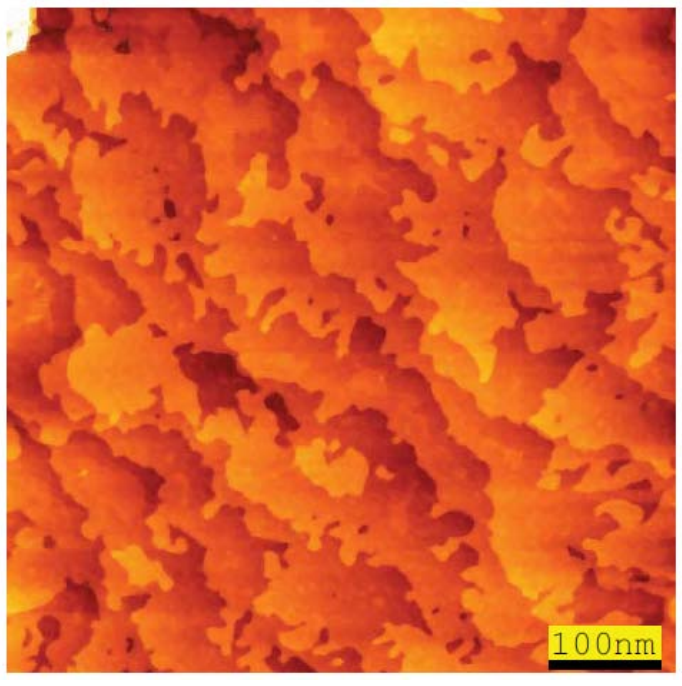


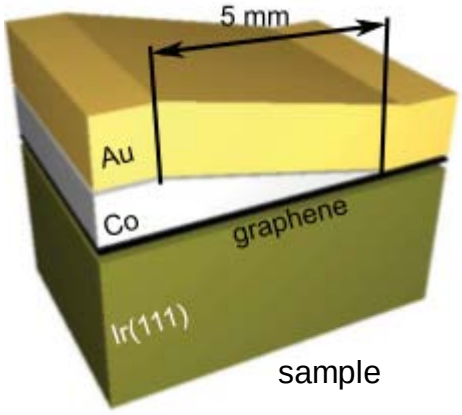


After annealing 400ºC

STM
(thickness 1.7nm)

Ultrathin Co on graphene

Pulsed-Laser Deposition

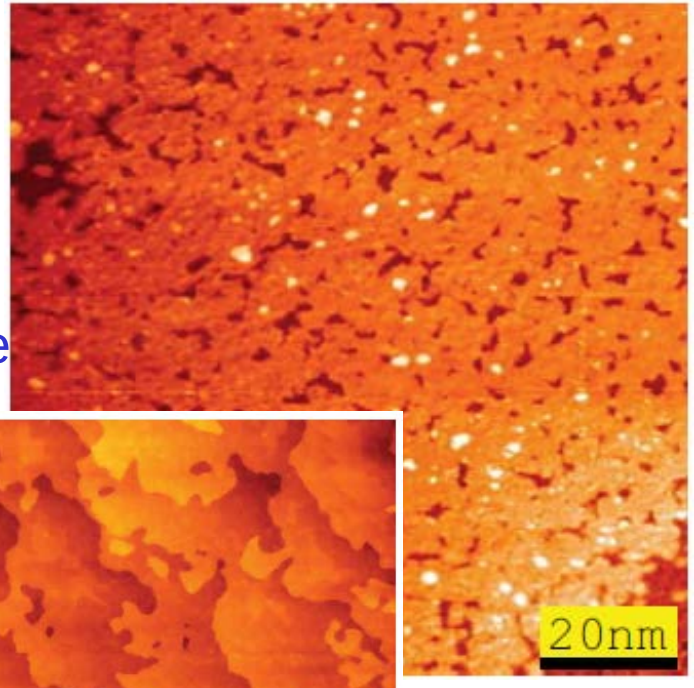


sample

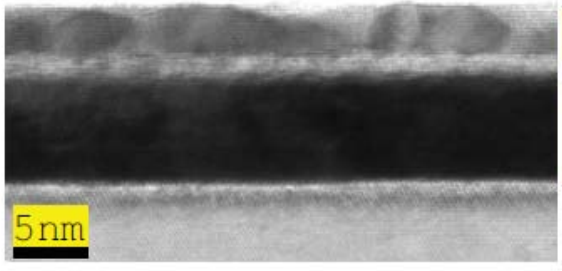
- Layer-by-layer growth up to 1.5nm
- Au-capping

STM
(thickness 0.8nm)

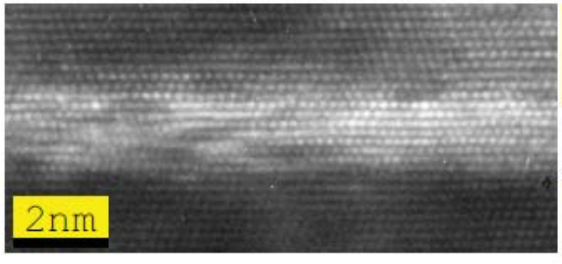
Growth at room temperature

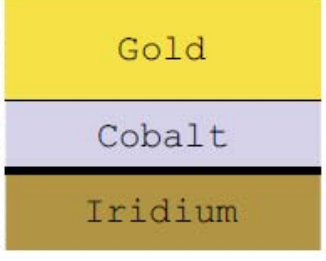


TEM (side-view)

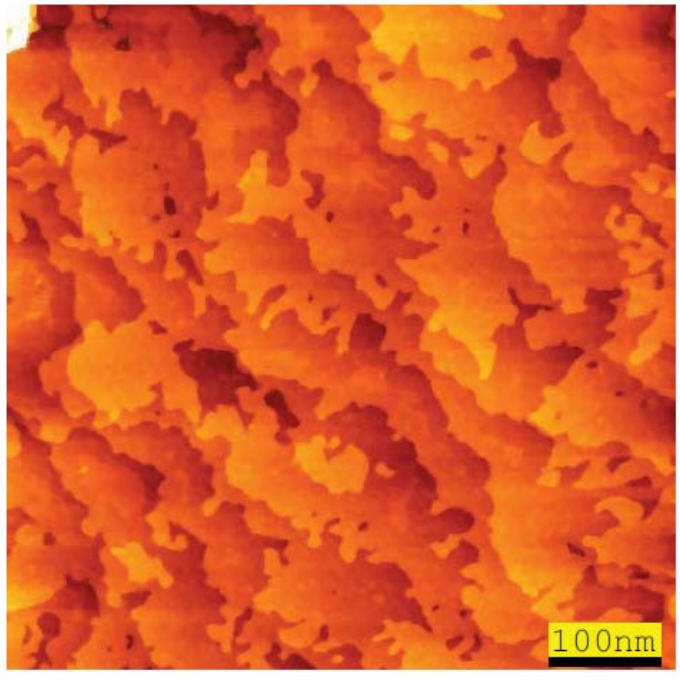


Gr.





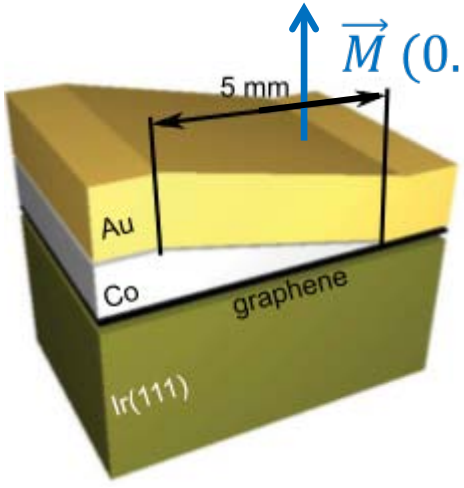
Gr.



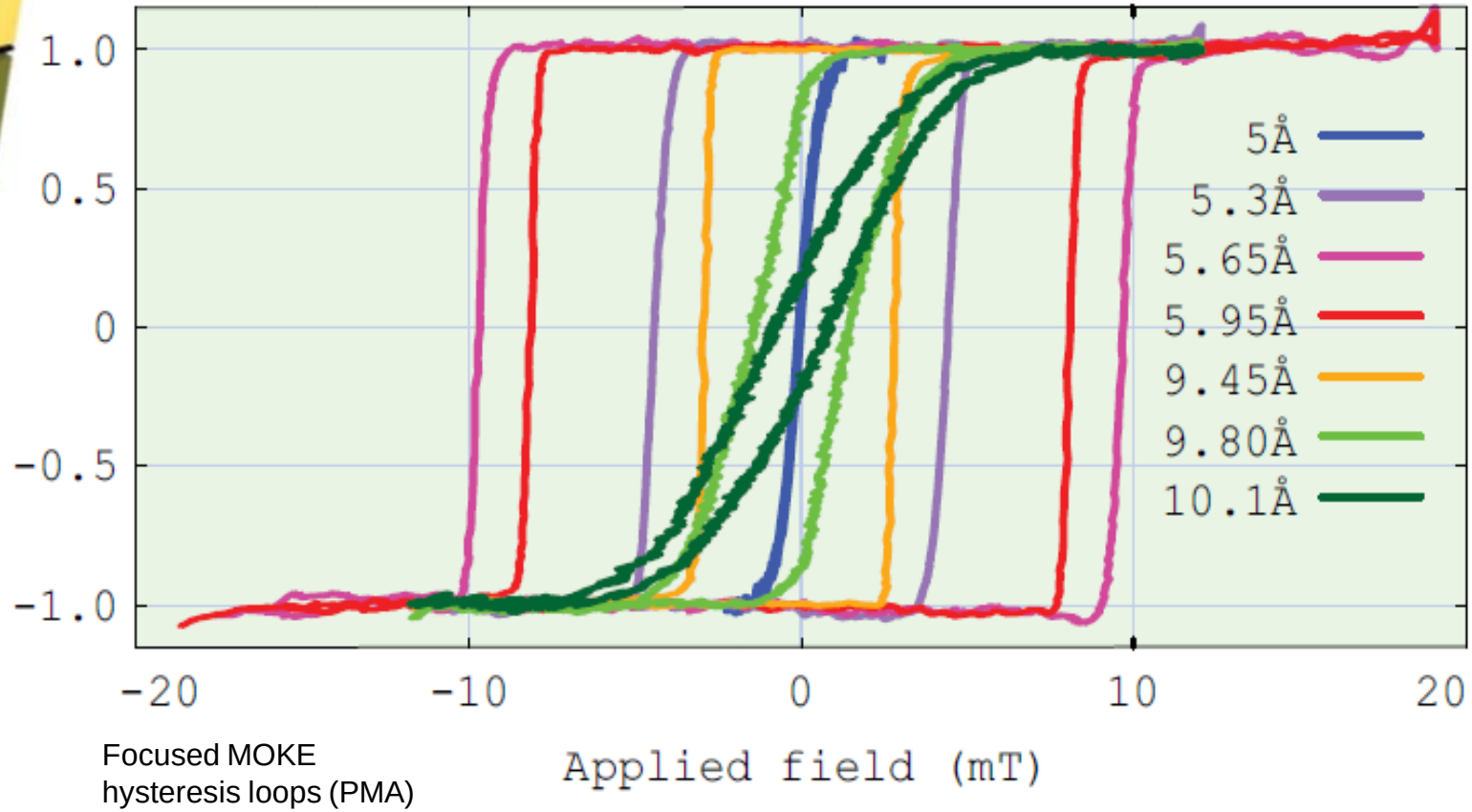
After annealing 400ºC

STM
(thickness 1.7nm)

Perpendicular magnetic anisotropy

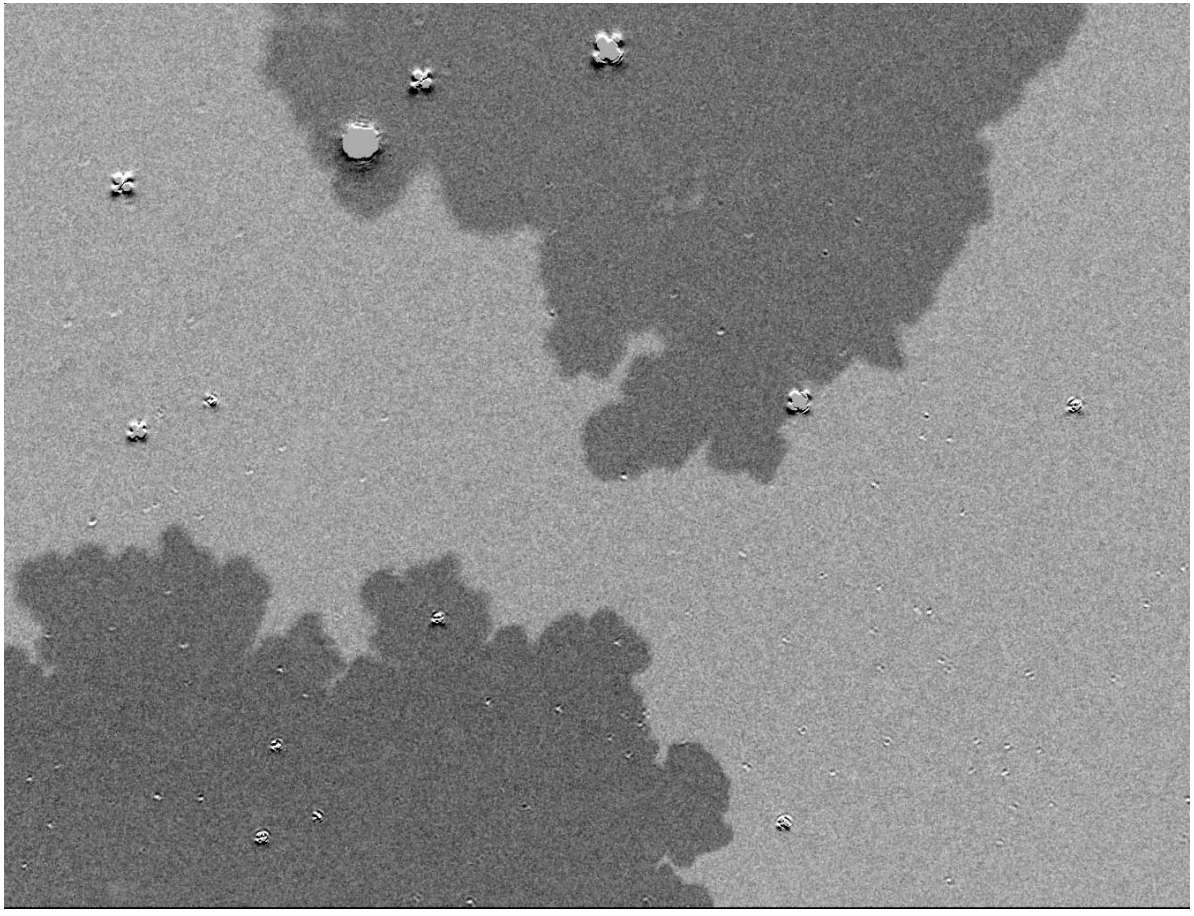


Reorientation transition seems abrupt

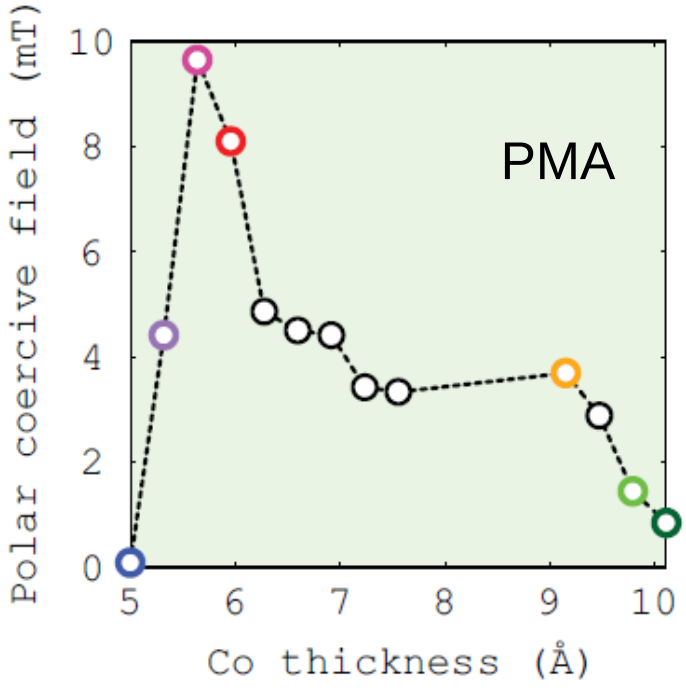


Focused MOKE
hysteresis loops (PMA)

Domain propagation



MOKE microcopy image 130 × 170 µm², ⊥ field: 4mT, thickness: 0.8 nm

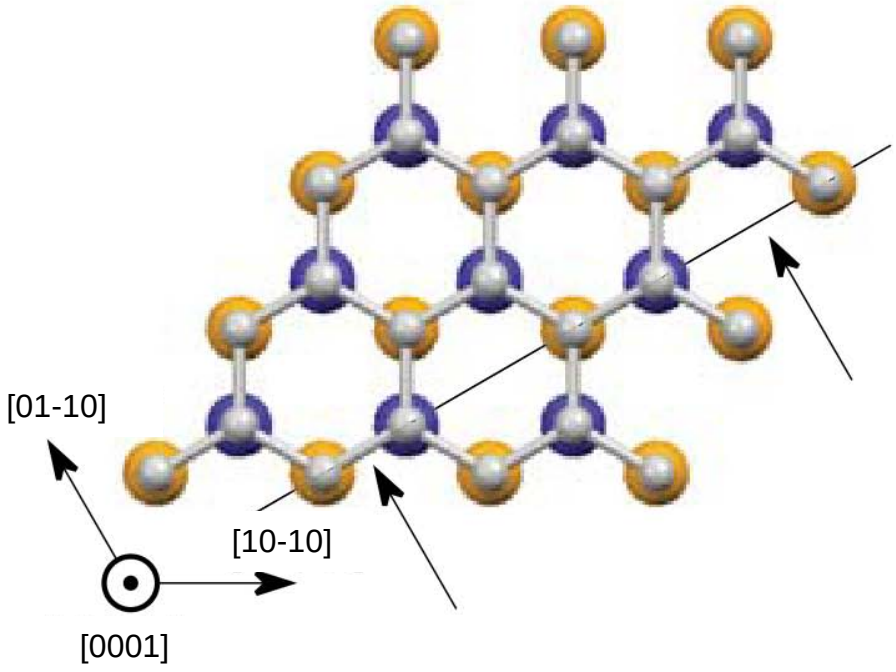


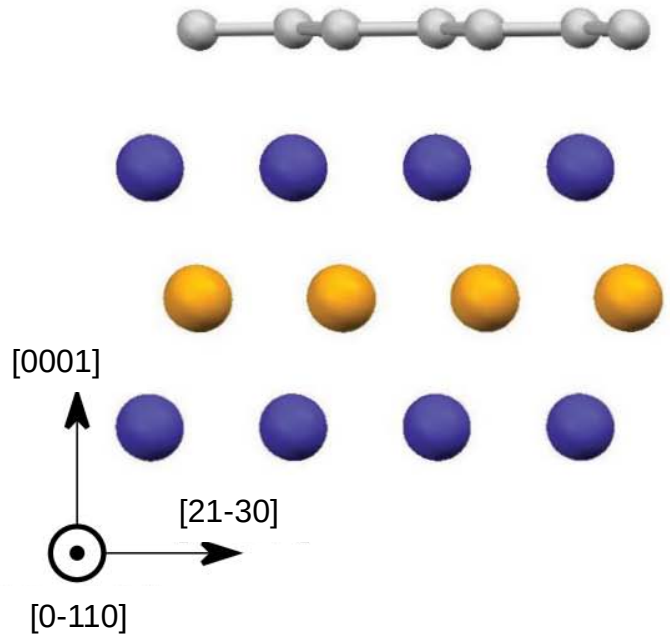
- Pd/Co/Pd, Au/Co/Au (111), Pt/Co/Pt(111)
- AlO_x/Co/Pt(111)

M. T. Johnson et al., Phys. Rev. Lett. **101**(2), 026803
B. Rodmacq et al., Phys. Rev. B **79**, 024423 (2009)

Origin of PMA?

Ab initio, spin polarized calculation with spin-orbit coupling

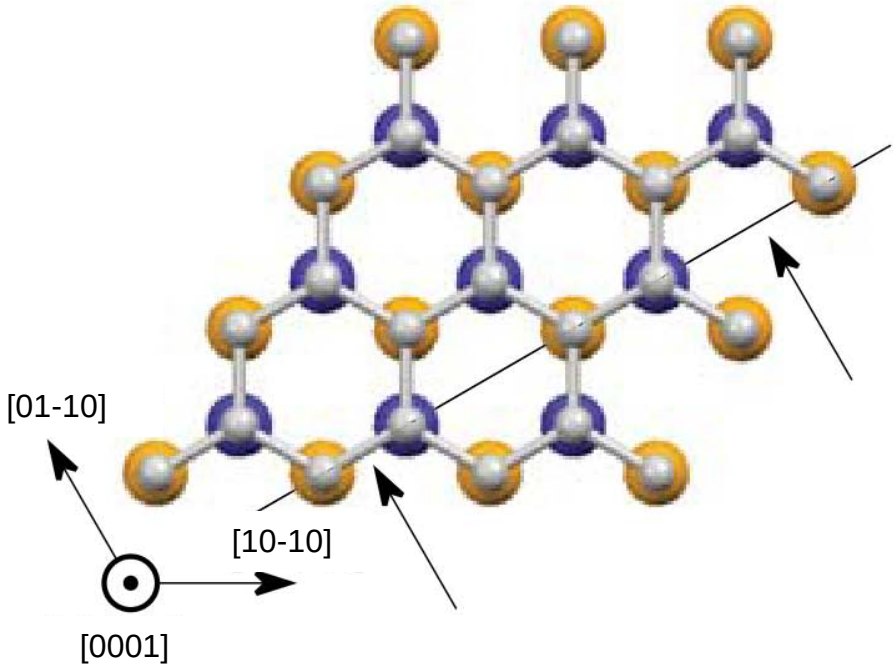


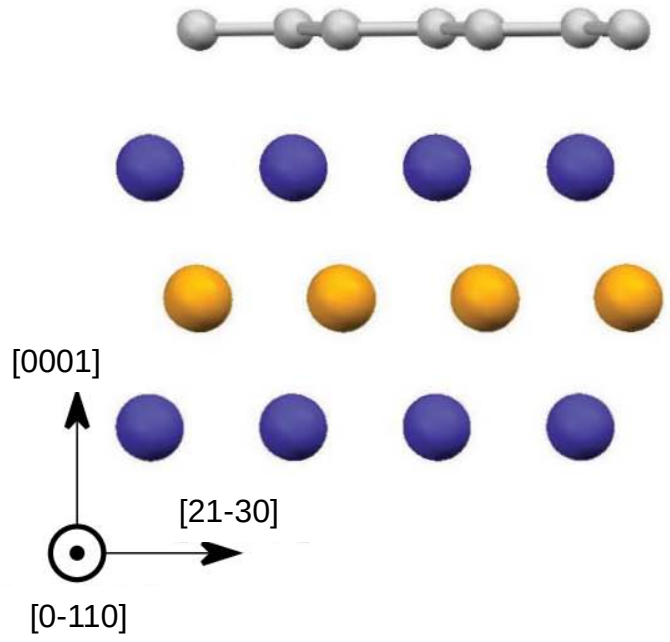


in-plane magnetization?

Origin of PMA?

Ab initio, spin polarized calculation with spin-orbit coupling



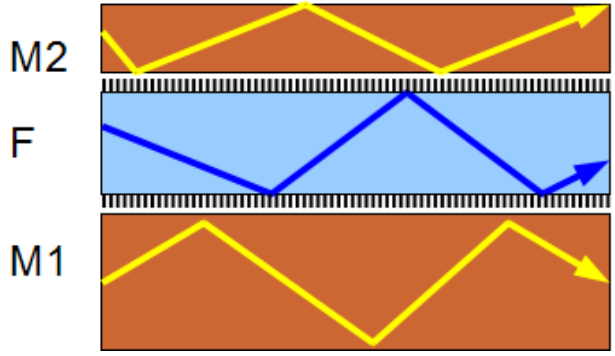


Graphene-Co: +0.8mJ/m^2

Au-Co: +0.6mJ/m^2

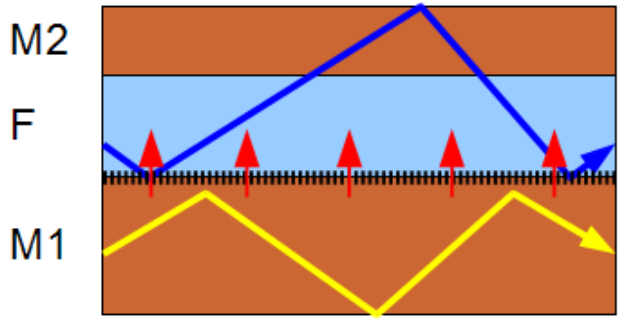
Perspectives

Force parallel channels for conduction



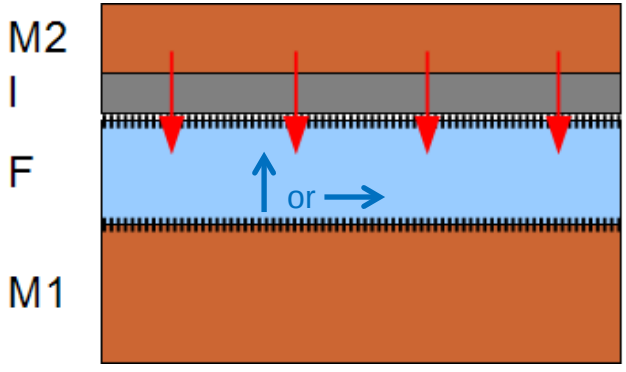
Keep a high polarization in Ferro (F)

Rashba-like effects for domain-wall motion



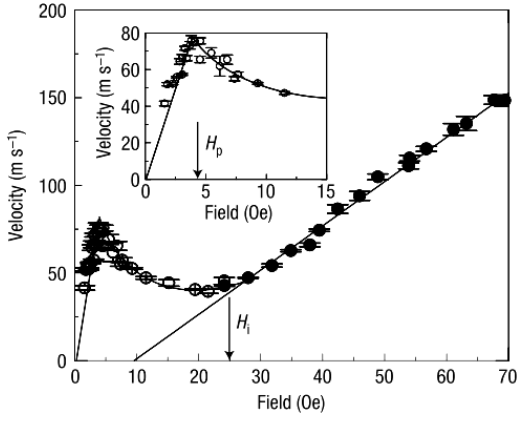
I. M. Miron et al., Nature. Mater. **9**, 230 (2010)

Electric field control of magnetism



M. Weisheit et al., Science **315**, 349 (2007)

Domain wall motion below the Walker breakdown



Beach et al., Nature Mater. **4**, 741 (2005)

Merci pour votre attention!

O. Fruchart, J. Coraux, J. Vogel, S. Pizzini, L. Ranno, C. Vo-Van, Z. Kassir-Bodon: Growth, Magnetic characterization, Hall conductance measurements

V. Santonacci, P. David: technical support

V. Salvador, P. Bayle-Guillemaud: TEM measurements

H. Yang, M. Chshiev: *ab initio* calculation