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# Local magnetic measurements in multi-layered nanowires observed by electron holography

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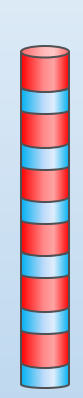
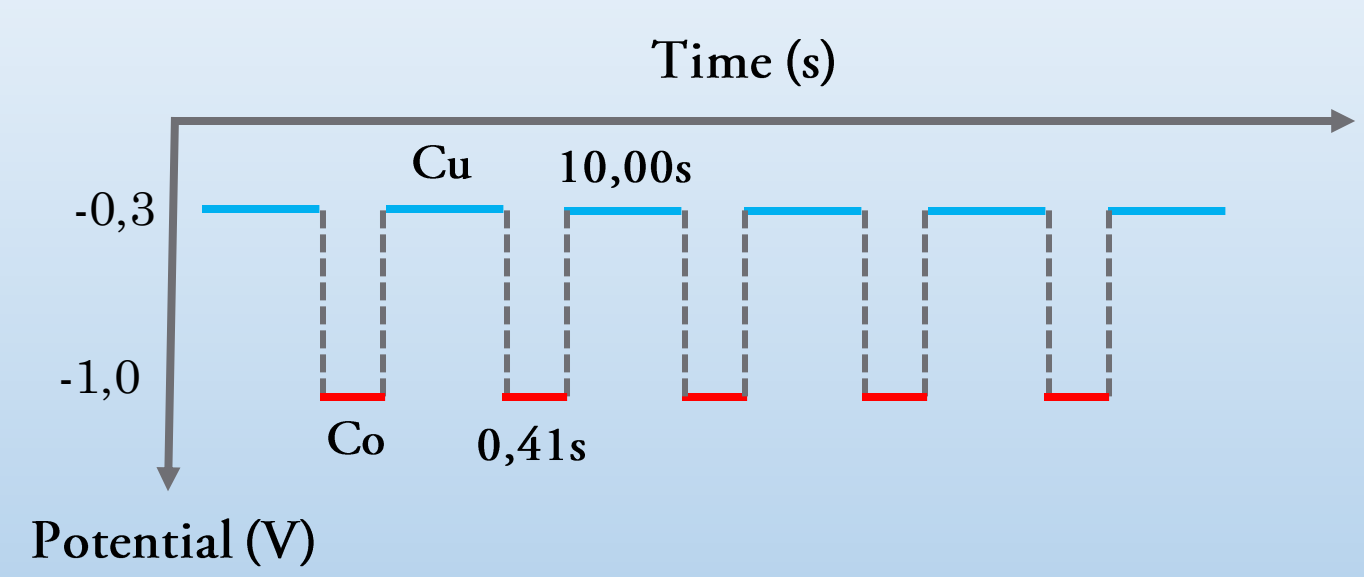
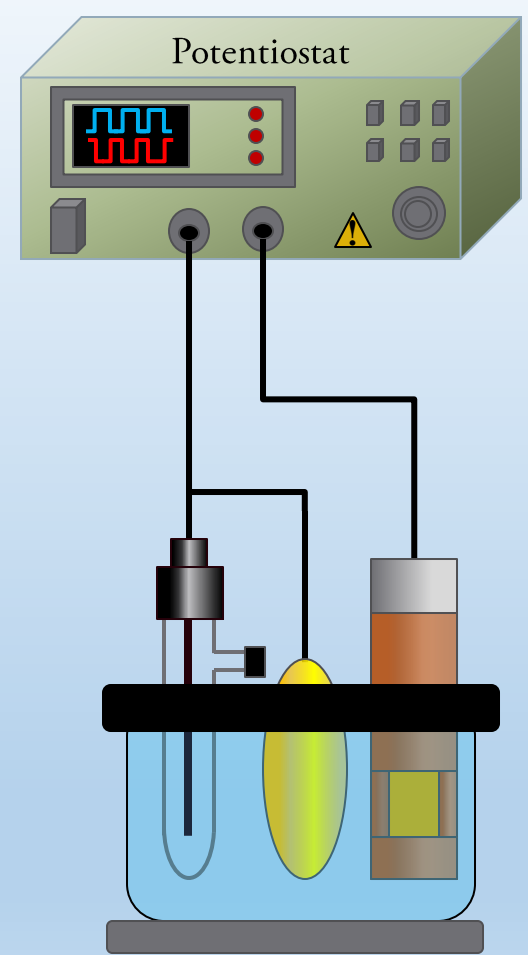
<sup>2</sup>Université Paul Sabatier, 31062, Toulouse, France

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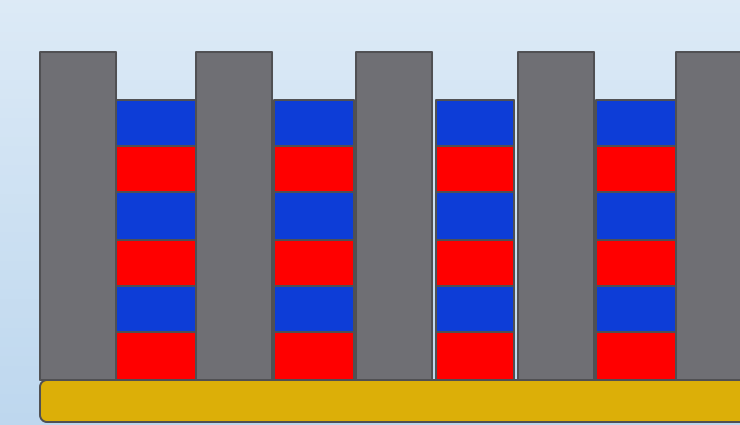
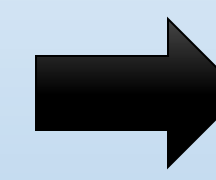
\* reyes@cemes.fr

In this study we elaborate multi-layered Co/Cu nanowires by pulsed electrodeposition technique into polycarbonate membranes, with a diameter between 55nm and 80nm. Cobalt and copper maps were obtained by EFTEM to get the position and the average thickness of the layers. Using electron holography we observed the magnetic states in individual cobalt layers for two different configurations.

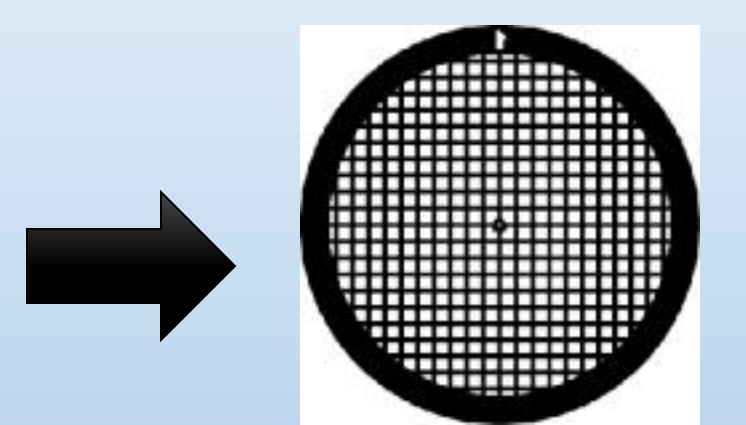
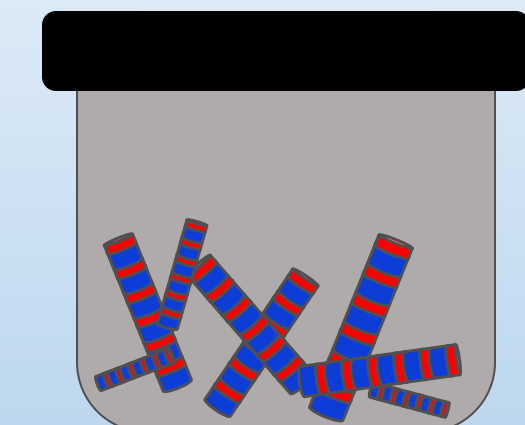
## Sample deposition



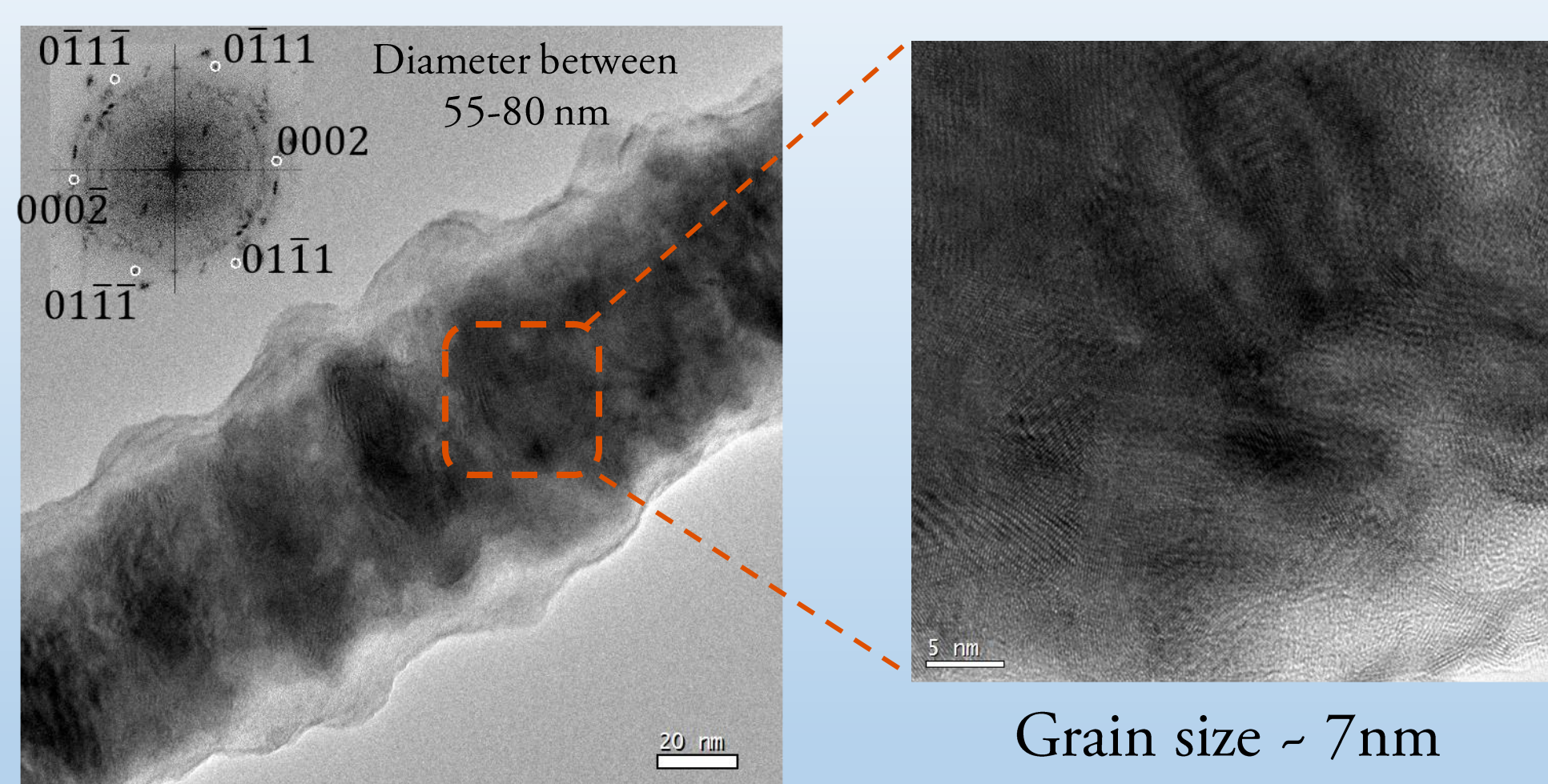
Polycarbonate membrane  
30 nm pore size



Membrane dissolution  
Dichloromethane



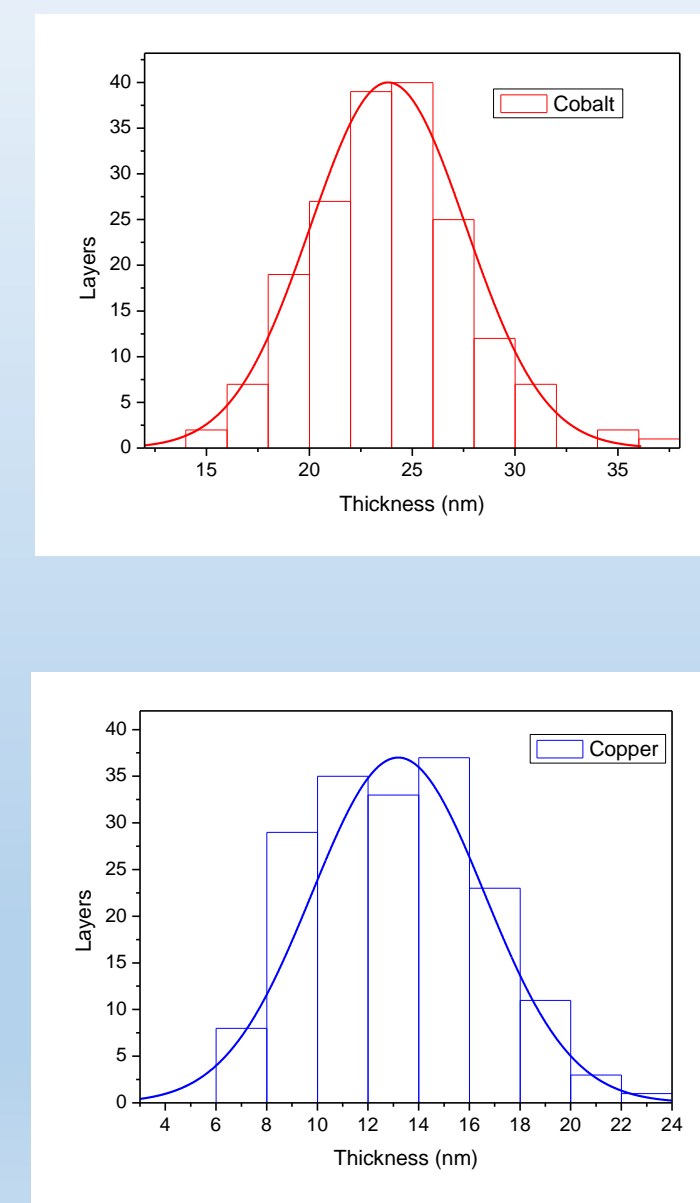
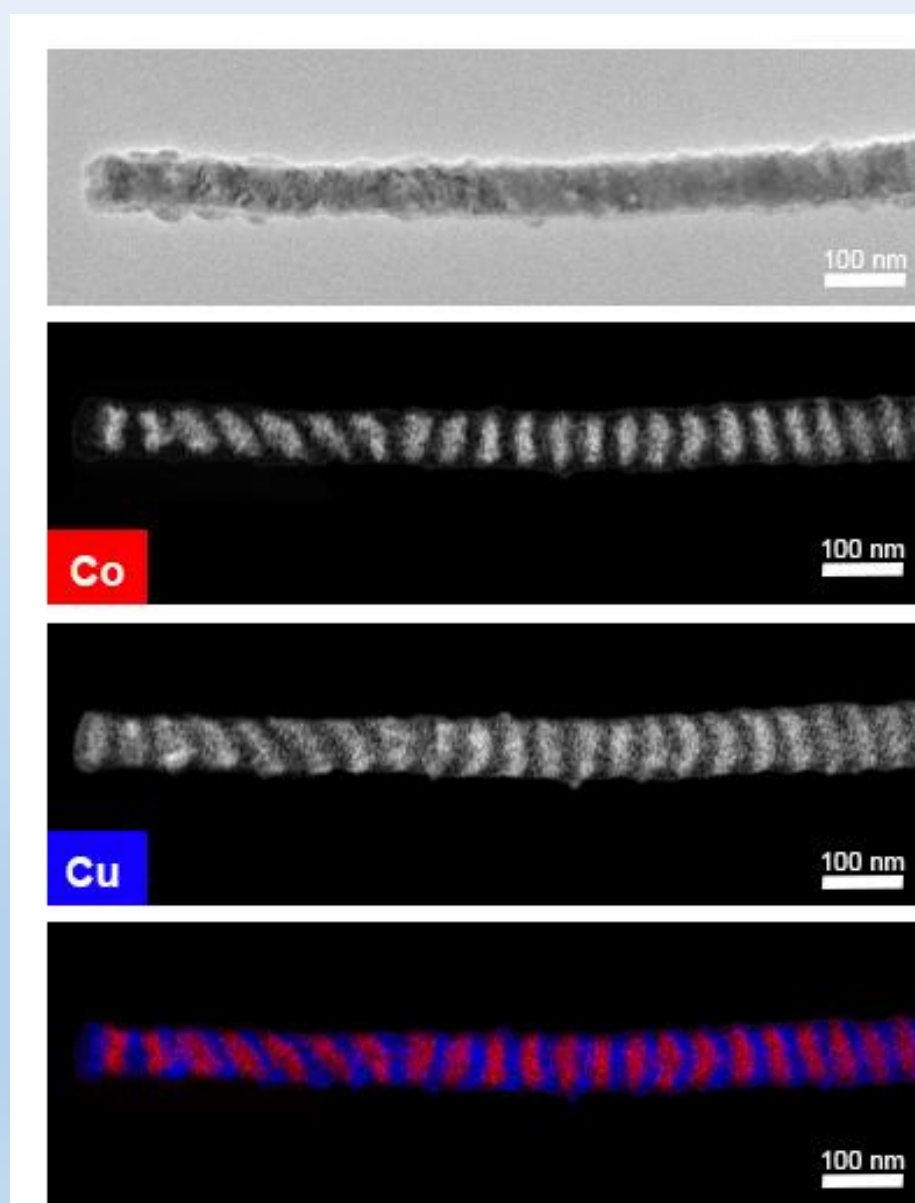
## Structural properties



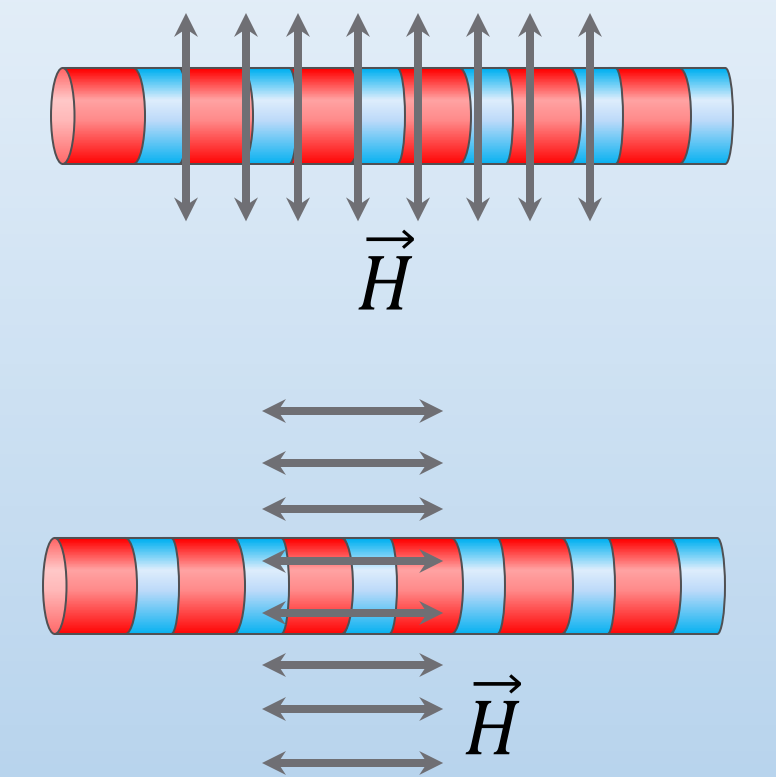
Polycrystalline with texture  
Co HCP and FCC  
Cu FCC

In the texture we could identify the c axis of the Co HCP  $\pm 20^\circ$  respect the axis wire

## Chemical properties



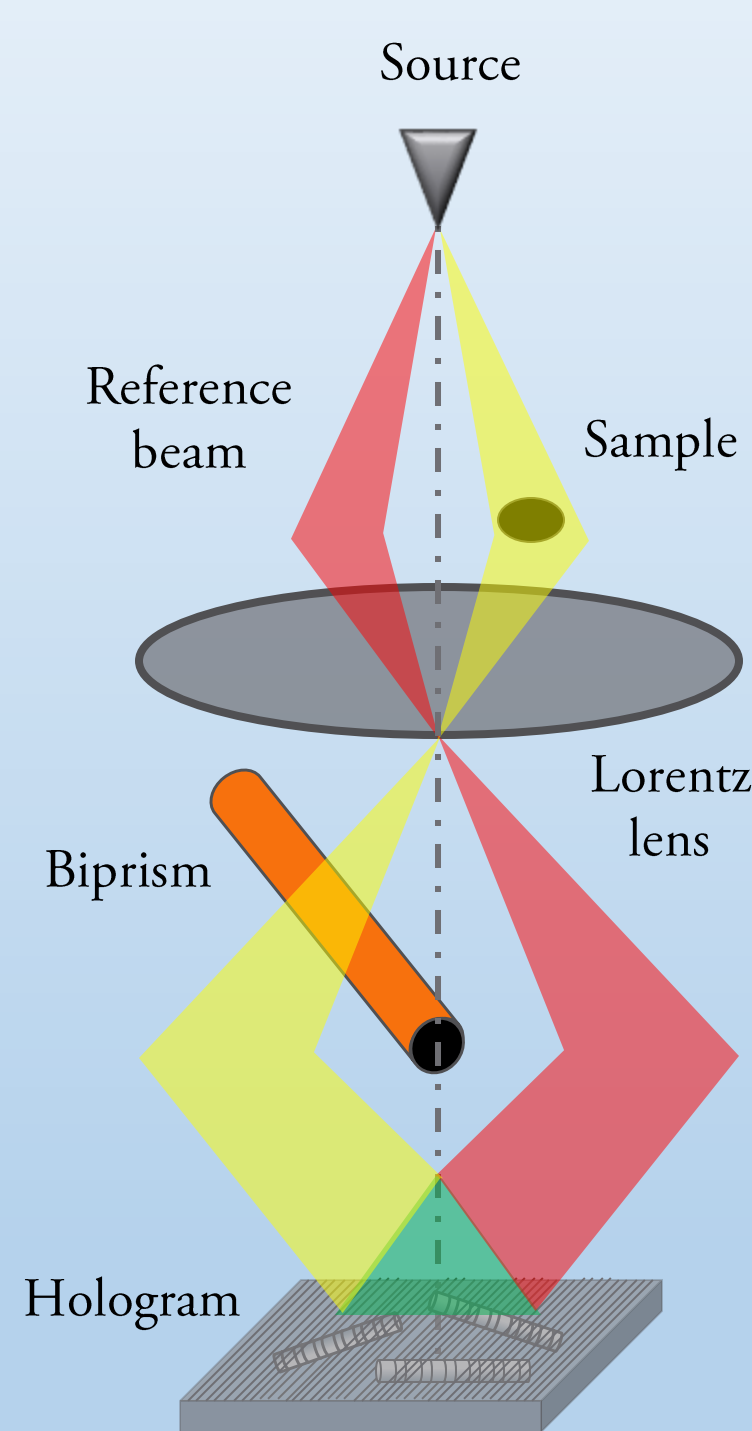
## Configurations



$\|\vec{H}\| = 1.3\text{T}$

Magnetic properties were observed in remanence state after apply a magnetic field

## Off-axis electron holography



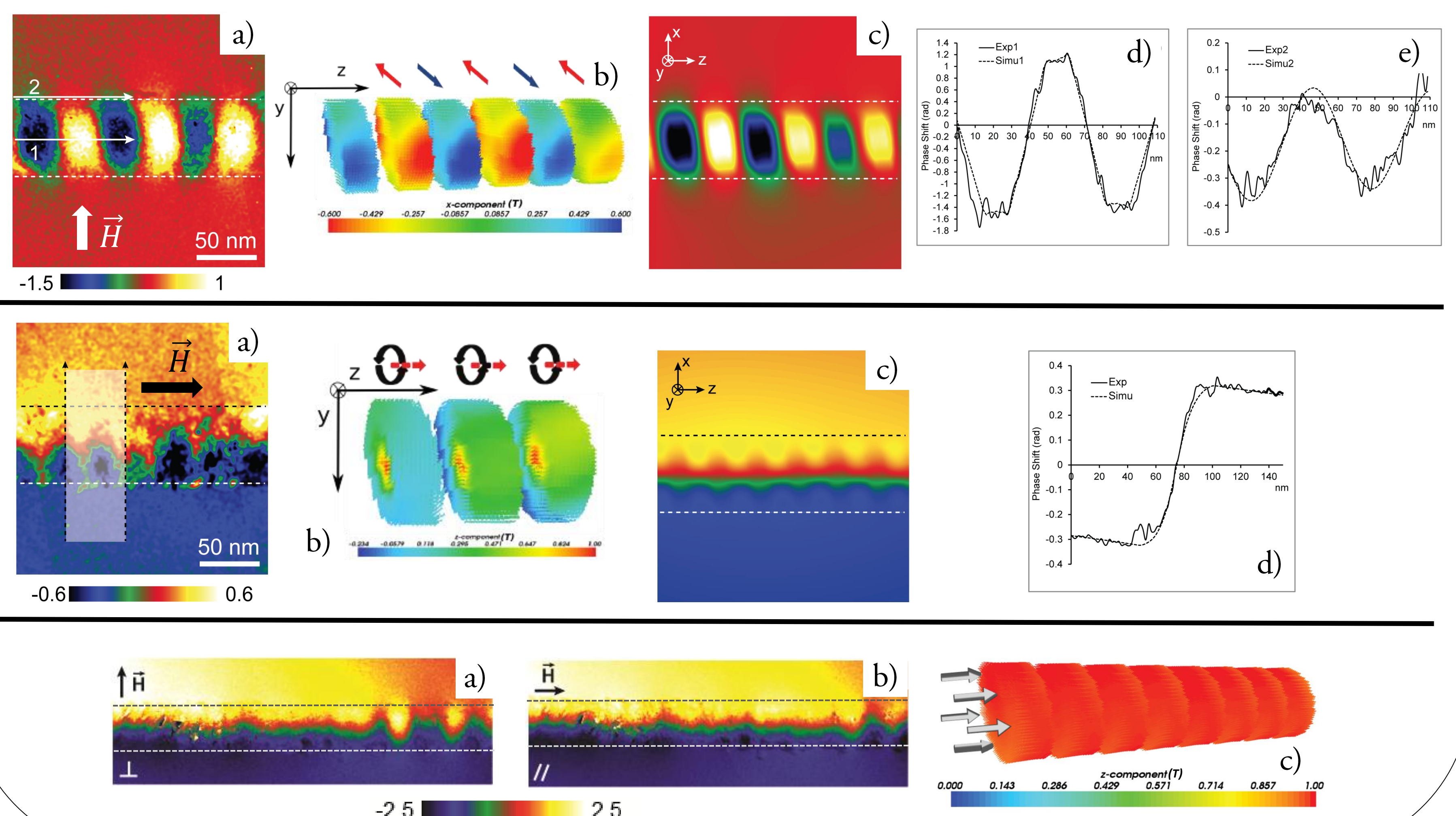
The phase of an electron wave that passed through a specimen will be changed by the electromagnetic by[1]:

$$\phi(x) = C_E \int V(x, z) - \frac{e}{\hbar} \iint B_{\perp}(x, z) dx dz$$

Mean inner potential (MIP):  $\phi^E(x) = C_E \int V(x, z)$

Magnetic contribution:  $\phi^M(x) = -\frac{e}{\hbar} \iint B_{\perp}(x, z) dx dz$

## Magnetic properties



## Conclusions

- We elaborate multi-layered Cu/Co nanowires by pulsed electrodeposition with a good quality
- Quantitative and local study combining structural, chemical, magnetic (electron holography) properties and 3D simulations
- We performed a systematic study of isolated nanowires with a spatial resolution no more of 2 nm by electron holography revealing 3 main configurations: a) antiparallel coupling, b) coupled vortices and c) monodomain state

## References

[1] Etienne SNOECK and Christophe GATEL, (2013). Transmission Electron Microscopy in Micro-nanoelectronics, WILEY, Chapter 5, pp. 108-126.

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