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## Growth and characterization of Cu/Co multi-layered nanowires

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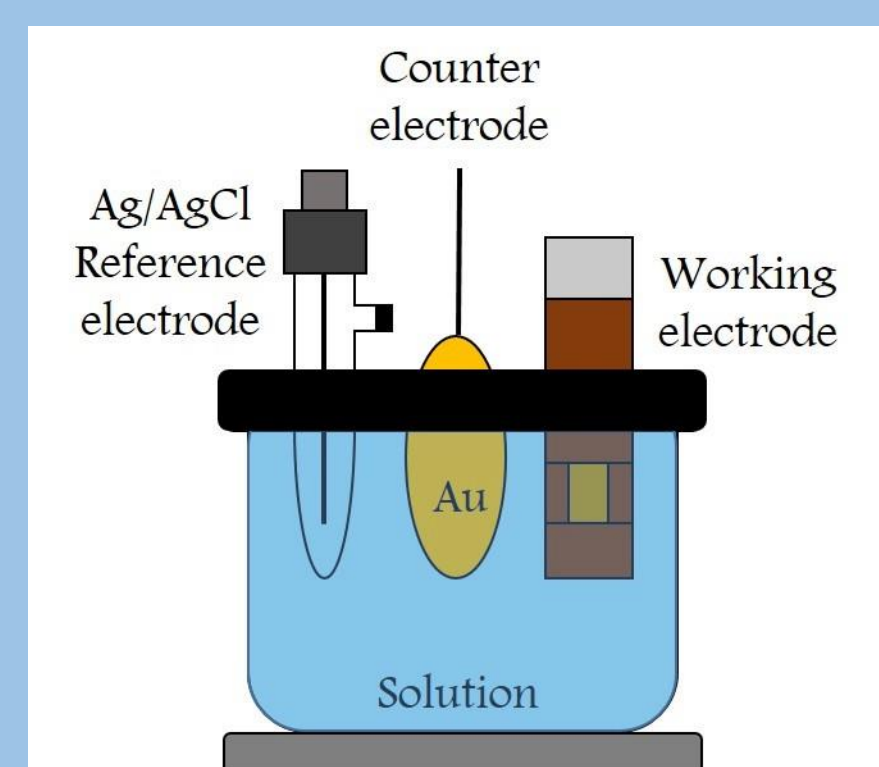
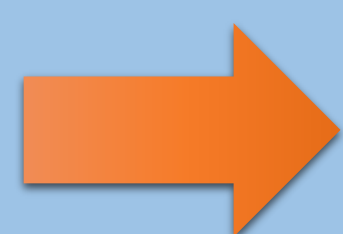
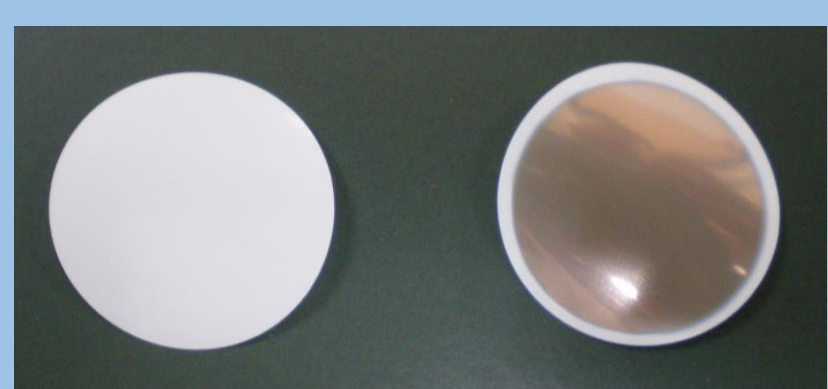
<sup>3</sup>LSI, École Polytechnique, 91128, Palaiseau, France

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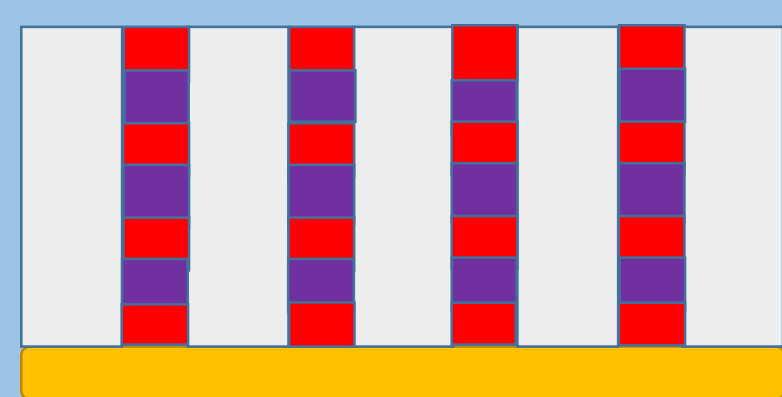
In this study we elaborate multi-layered Co/Cu nanowires by pulsed electrodeposition technique into polycarbonate membranes, their mean diameter is 50nm. Cobalt and copper maps were obtained by EFTEM to get the position and the average thickness of the layers. Using electron holography we observed the magnetic states in individual cobalt layers.

## Sample preparation

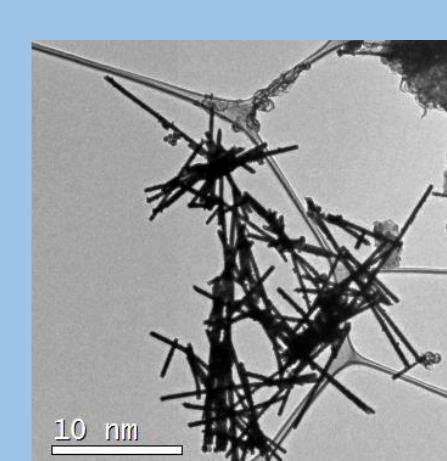
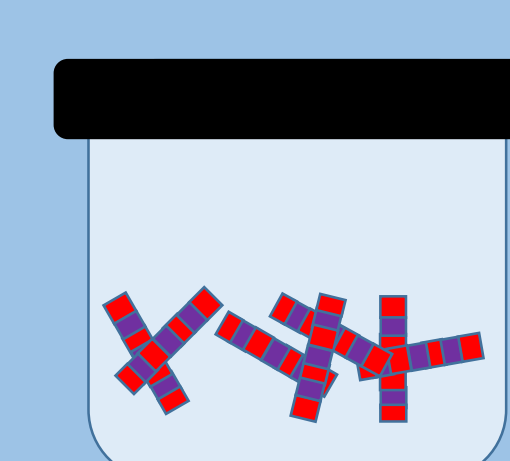
Polycarbonate membrane



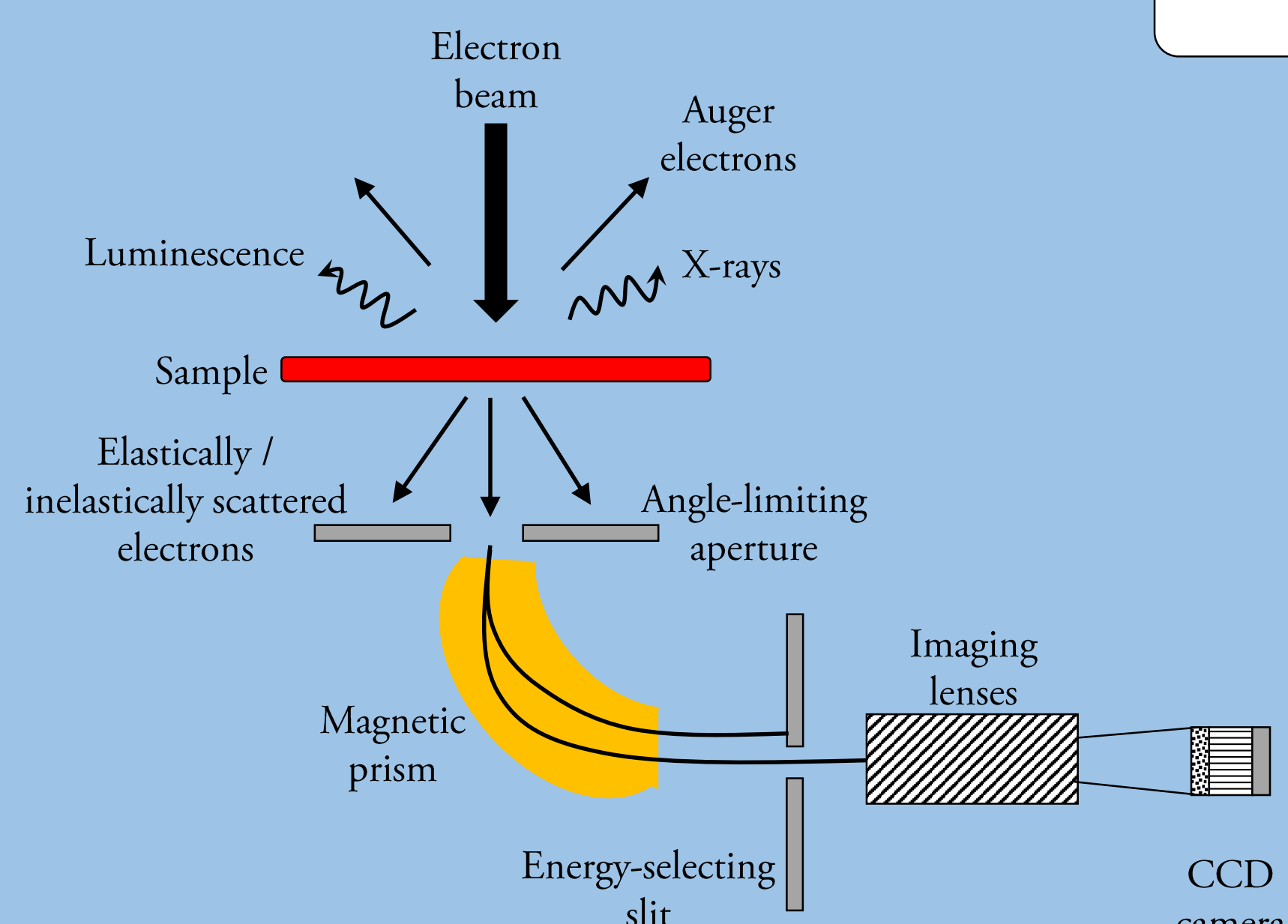
Pulsed electrodeposition



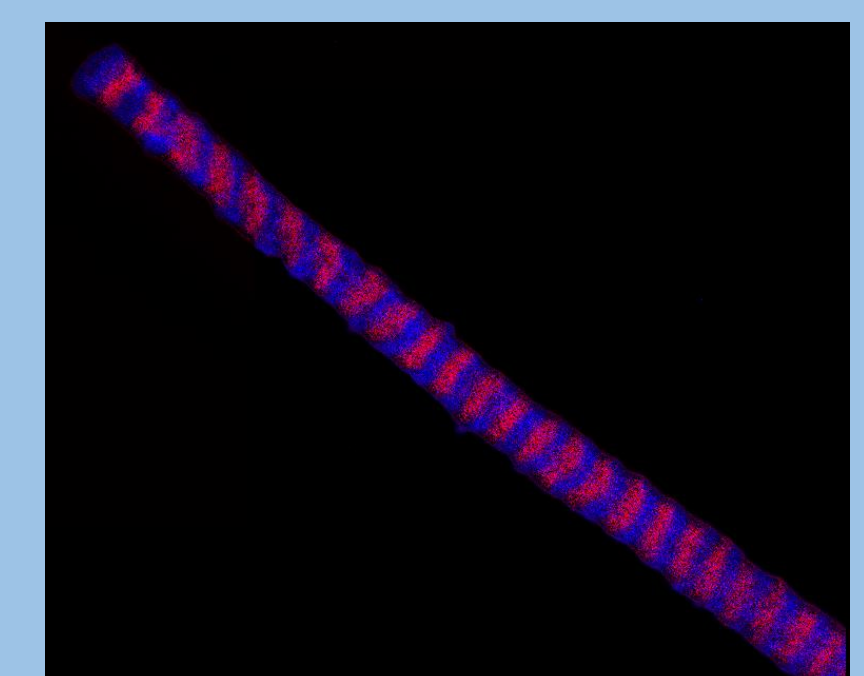
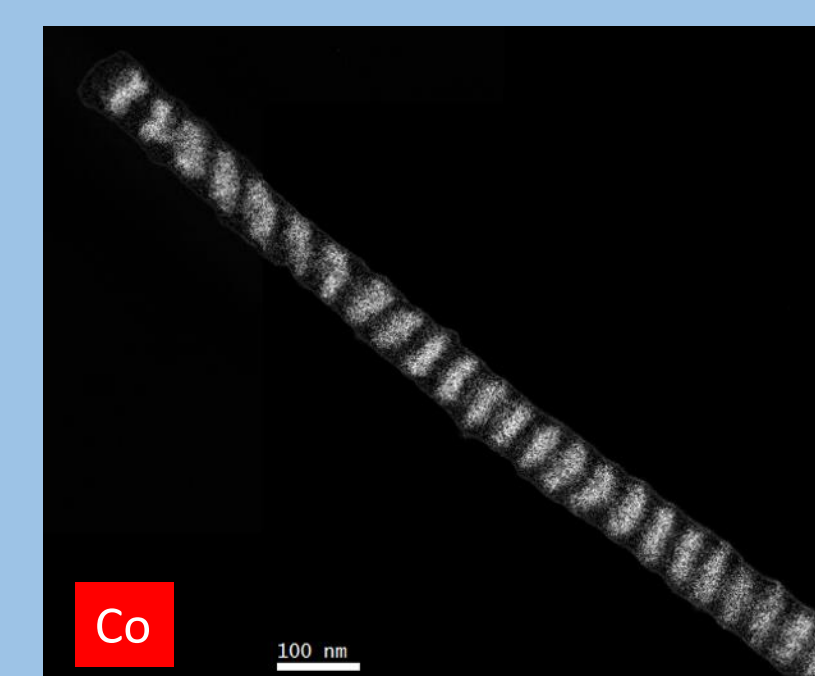
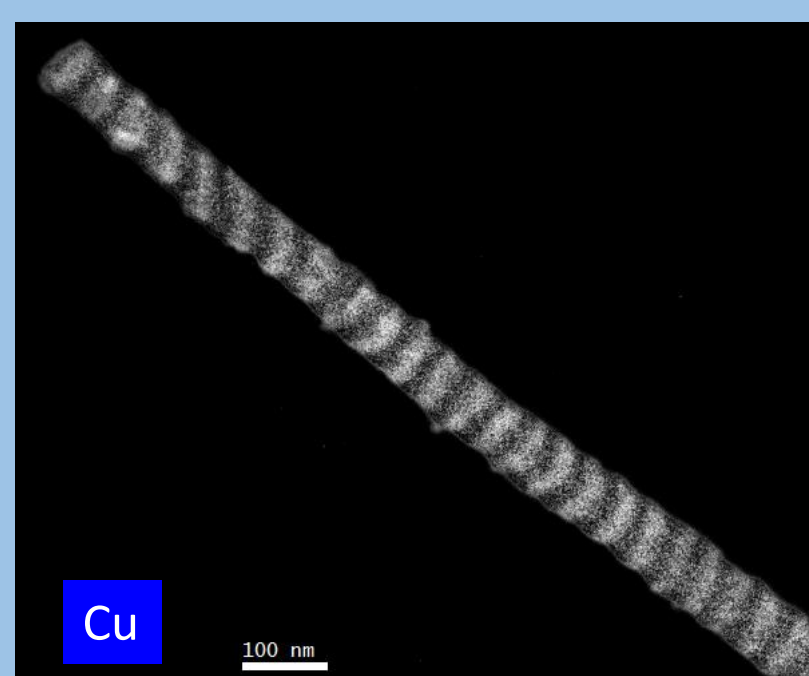
Membrane dissolution and  
Obtained the sample



## EFTEM



Scheme of the EFTEM arrangement[2]



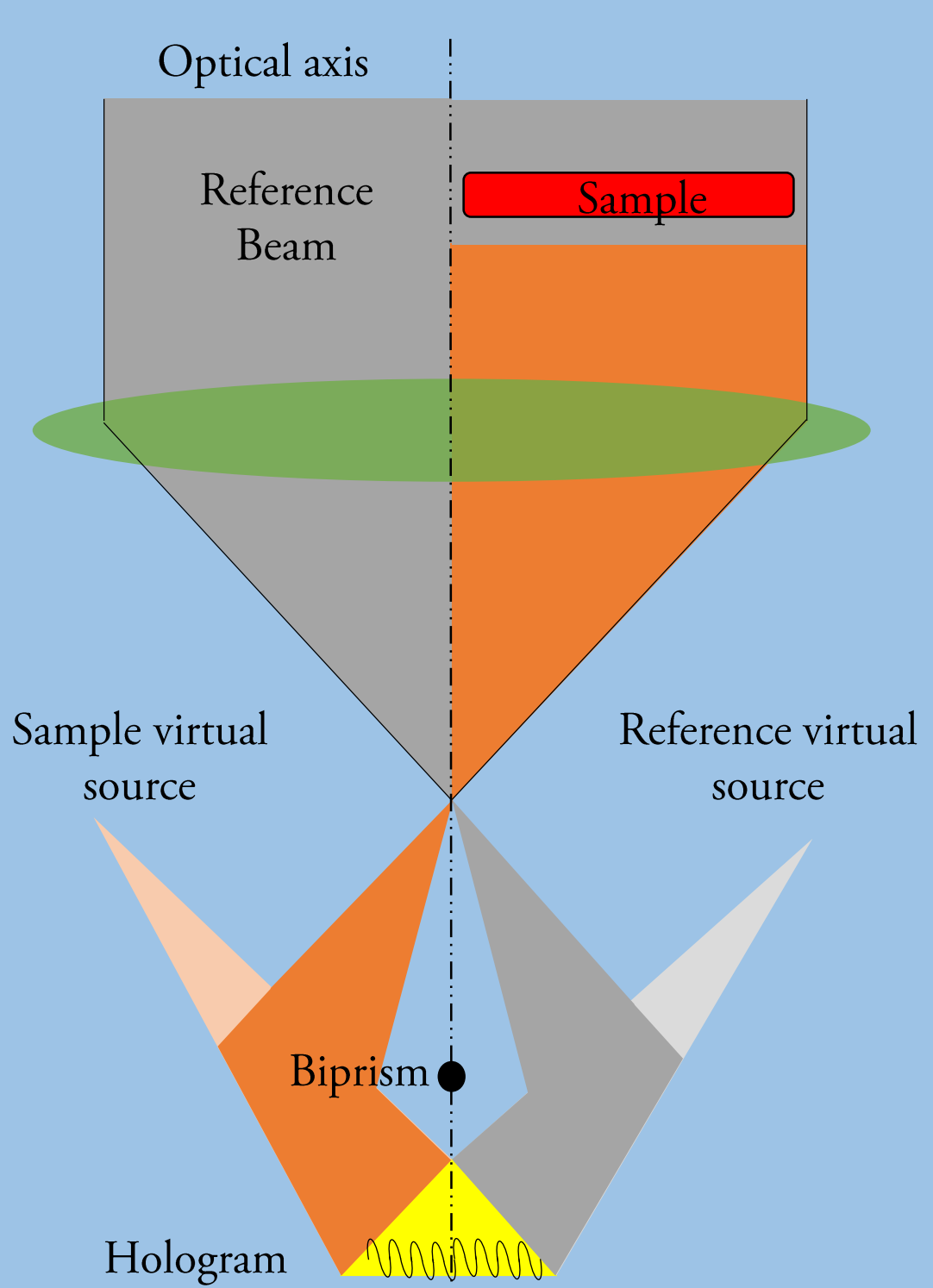
EFTEM maps for the copper, cobalt and the color map

$$\bar{t}_{Cu} = 13.2nm \quad \sigma_{Cu}^2 = 3.4nm$$

$$\bar{t}_{Co} = 23.8nm \quad \sigma_{Co}^2 = 3.8nm$$

Layer thickness for the Co and Cu

## Electron holography



Scheme of the off-axis electron holography

The phase of an electron wave that passed through a specimen will be changed by the electromagnetic field. This phase change is given by[1]:

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

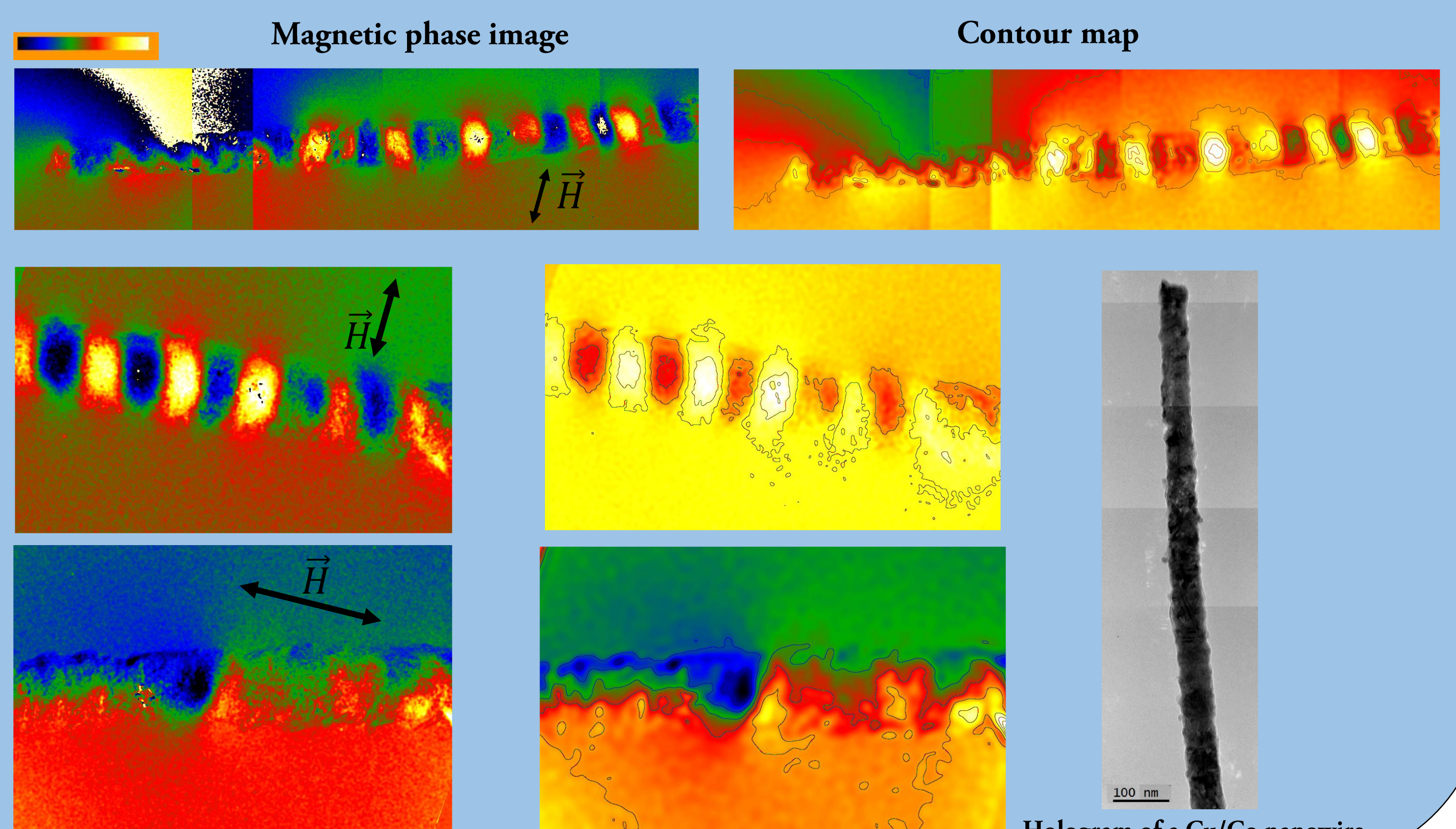
The total phase shift can be separated into two terms:

$$\phi^E(x) = C_E \int V(x, z)$$

Electrostatic contribution: MPI and possible additional local electrical potential

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

Magnetic contribution: result of the Lorentz force



Hologram of a Cu/Co nanowire

## Conclusions

- We elaborate multi-layered Cu/Co nanowires by pulsed electrodeposition technique.
- The thickness of the layers was measured by EFTEM obtaining 23nm for the Co and 13nm for the Cu
- The magnetic states were studied by electron holography finding an antiparallel coupling between the Co layers along the wires when a magnetic field is applied perpendicular to the wire axis and other different magnetic states when the magnetic field is applied parallel to the wire axis

## References

- [1] Etienne SNOECK and Christophe GATEL, (2013). Transmission Electron Microscopy in Micro-nanoelectronics, WILEY, Chapter 5, pp. 108-126.  
 [2] David B. Williams, C. Barry Carter, (2009). Transmission Electron Microscopy A Textbook for Materials Science, Springer, Chapter 37, pp. 679-683.

## Acknowledgments

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