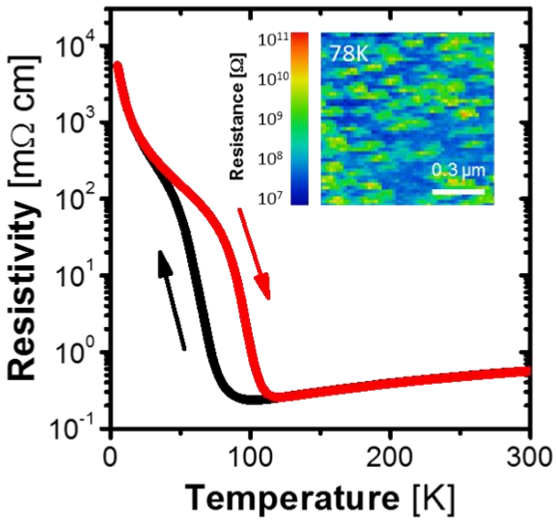
Unité Mixte de Physique CNRS/Thales – Université Paris-Saclay – 1 avenue Fresnel – 91767 Palaiseau- France

MASTER THESIS PROPOSAL (M2) 2016-2017

Nanoscale imaging of a first-order metal-insulator transition by low-temperature conducting atomic force microscopy

Transition metal oxides possess a broad range of functionalities (superconductivity, magnetism, ferroelectricity, multiferroicity) stemming from the interplay between structural effects and electronic correlations. A particularly interesting family of materials is the rare-earth nickelate series ($RNiO_3$, RNO) [1]. Except for $LaNiO_3$ that is metallic at all temperatures, RNO compounds display a metal-insulator transition at a temperature TMI that depends on the size of the rare-earth cation R. In $NdNiO_3$ for instance, the transition occurs around 100 K and corresponds to a jump in resistance by more than 4 orders of magnitude as the sample is cooled through the TMI (cf. Figure). This transition is strongly hysteretic with temperature, signalling a first-order character. As such, through the transition, the material is expected to exhibit a phase-separated state with coexisting metallic & insulating regions. Although indications of this phase separation have been obtained indirectly by photoemission measurements[2], there have been no direct imaging of the resistance across the transition.



The goal of the present internship is to perform conductive atomic force microscopy (cAFM) experiments[3] as a function of temperature on $NdNiO_3$ thin films, in order to map the phase-separated state across the metal-insulator transition. The resistance maps will then be analysed in detail, and the temperature dependence of the relative fraction of metal and insulating regions will be extracted, as well as their size and morphology. The figure shows a very preliminary result obtained in our lab, showing the feasibility of the experiment.

[1] S. Middey, J. Chakhalian, P. Mahadevan, J.W. Freeland, A.J. Millis, and D.D. Sarma, Annu. Rev. Mater. Res. **46**, 305 (2016).
[2] G. Mattoni, et al, ArXiv/1602.04445 (2016).
[3] M. Basletic, J.-L. Maurice, C. Carrétéro, G. Herranz, O. Copie, M. Bibes, E. Jacquet, K. Bouzehouane, S. Fusil, and A. Barthélémy, Nature Mater. **7**, 621 (2008).

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Techniques in use: Conductive atomic force microscopy at low temperatures
Applicant skills: Strong affinity for experimental work, perseverance, good organization skills, electronics, condensed-matter physics
Allowance: >400 €/month **Possibility to extend by a PhD thesis:** No