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Unveiling Metal-Insulator Transitions in $(V_{1-x}Cr_x)_2O_3$ through in situ Monochromatized STEM/EELS

Dr. Abdelali Khelfa[1], Mr. Jean-Denis Blazit[1], Mr. Luiw H. G. Tizei[1], Mr. Etienne Janod[2], Mr. Julien Tranchant[2], Mr. Benoît Corraze[2], Mr. Laurent Cario[2], Mrs. Odile Stephan[1], Mrs. Laura Bocher[1]
[1]Laboratoire de Physique des Solides - Université Paris Saclay - CNRS, Orsay (91405), France, [2]Institut des Matériaux Jean Rouxel - Université de Nantes - CNRS, Nantes (44322), France

Background incl. aims

The exploration of insulator-to-metal transitions (IMTs) in Mott insulators and strongly correlated systems has revealed intriguing phenomena induced by various stimuli such as temperature, pressure, doping, or electric fields [1,2]. Despite significant advancements, the mechanisms governing electronic phase separation at the nanoscale remain elusive. Addressing this knowledge gap requires a comprehensive approach, considering structural and electronic degrees of freedom. In this context, our study aims to investigate the temperature-driven IMT in $(V_{0.988}Cr_{0.012})_2O_3$ (see Figure a), employing advanced techniques capable of probing multiple features simultaneously. The Cr-doping enables us to explore transitions from the paramagnetic insulator (PI) phase to the paramagnetic metallic (PM) phase around 200 K and also from the PM phase to the antiferromagnetic insulator (AFI) phase below 180 K. Interestingly, the PI/PM transition is isostructural of the hexagonal structure (space group R-3c) while the PM/AFI transition is associated with a crystallographic symmetry breaking into a monoclinic structure (space group I2/a). There is, therefore, a strong interest in investigating both spectroscopically and structurally this material using the same in situ tool.

Methods

To achieve our objectives, we employ in situ monochromatized EELS [2] and 4DSTEM micro/nano-diffraction [3] techniques. These experiments are conducted using a state-of-the-art NION Ultra-HERMES 200 microscope, equipped with a Medipix direct detector and a HennyZ double tilt cryo-holder. This cutting-edge instrumentation allows us to unravel intricate details associated with the IMT process.

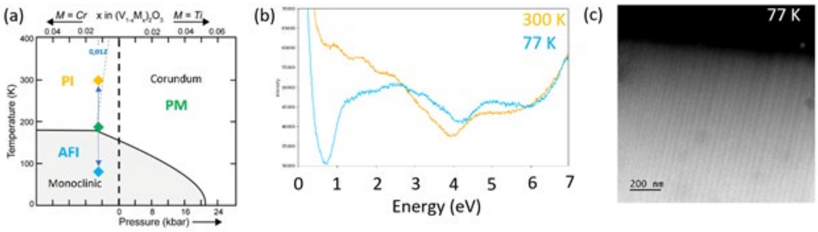
Results

Specifically, we focus on identifying variations in low-loss spectra, highlighting fingerprints of the PI, PM, and AFI phases (Figure b). By comparing structural information acquired by 4DSTEM with such spectroscopic signatures, we probe a phase coexistence at low temperatures, as depicted in Figure c [4].

Conclusion

Overall, our results highlight the instrumental capabilities of high-energy resolution EELS as a valuable tool for unraveling the intricate dynamics of IMTs, offering new perspectives on the underlying physics of these fascinating phenomena.

Graphic:



Keywords:

Mott-Insulators, IMT, In-Situ, EELS, 4DSTEM

Reference:

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