INTENSIVE COURSE: OXIDE INTERFACES
1:30-5PM WEDNESDAY MARCH 21, APRIL 4, 11, 18 2012
AMPHITHEATRE FRESNEL, ECOLE POLYTECHNIQUE

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Oxide Nanostructures, artificially created systems interweaving transition metal oxides with different electronic properties, can now be fabricated with atomic precision. This experimental success raises fundamental challenges in physics and applied science in understanding the new phenomena which have been observed, determining how to use the new control modalities to obtain new systems with desired electronic properties (for example, high temperature superconductivity, or metallic ferromagnetism) and putting the new phenomena to practical use.

This intensive course will survey the current status of the field, discuss the basics of atomic and electronic structure, present the concepts and techniques needed to understand and exploit the new potentialities and outline the open questions and challenges. It is is intended to be useful both to students interested in the area and researchers active in the field.

Format: ~2 hours of lecture followed by a seminar on a topic of current research.

Course Schedule

- **March 21: Survey of phenomena and introduction to basic concepts**
  Seminar: J. Leseur, ESPCI
  Properties of the two-dimensional electron gas at the Mott-Insulator Band-Insulator $LaTiO_3/SrTiO_3$ *interface*
- **April 4: the interface–**LAO/STO **and related systems: magnetism and superconductivity**
  Seminar: M. Gabay, Orsay
  From strange insulator to spin-orbit conductor: unveiling orbital selectiveness at the $LaAlO_3 - SrTiO_3$ *interface*
- **April 11: Heterostructures and the metal insulator transition**
  Seminar: M. Gibert, Universite de Geneve
  Nickelate based thin films and heterostructures"
- **April 18: Driven systems and potential applications**.
  Seminar: M Bibes
  Magnetoresistance and electroresistance in tunnel junctions based on transition-metal perovskites

Course Outline

- **March 21**: Survey of phenomena and introduction to basic concepts. Goals of field, enumeration of systems of current interest, introduction to experimental techniques, outline of electronic structure including charge densities, length scales, band alignments and polar catastrophe.
  Suggested Reading:
  - *Metal insulator transitions*, Imada, M., Fujimori, A. and Tokura, Y. . Rev. Mod. Phys. **70**, 10391262 (1998).
  - *Artificial charge-modulation in atomic-scale perovskite titanate superlattices*, A. Ohtomo, D. A. Muller, J. L. Grazul and H. Y. Hwang, Nature **419**, 378-380 (2002).
  - *Polar heterojunction interfaces* Harrison, W. A., Kraut, E. A., Waldrop, J. R. Grant, R. W. . Phys. Rev. **B18**, 44024410 (1978).
  - *Engineered interface of magnetic oxides* Yamada, H. et al.. Science **305**, 646648 (2004).
  - *Why some interfaces cannot be sharp.* Nakagawa, N., Hwang, H. Y. and Muller, D. A., Nature Mater. **5**, 204209 (2006).
- **April 4**: the interface–LAO/STO and related systems: magnetism and superconductivity. Description of $LaAlO_3/SrTiO_3$ system; electronic structure from theory and experiment; superconductivity, magnetism and metal-insulator transition.
  Suggested Reading:
  - *Emergent phenomena at oxide interfaces*, H. Y. Hwang, Y. Iwasa, M. Kawasaki, B. Keimer, N. Nagaosa and Y. Tokura, *Nature Materials* **11** 103 (2012).
  - *Origin of the Two-Dimensional Electron Gas Carrier Density at the $LaAlO$3 on $SrTiO$3 Interface*, Popovic, Zoran S., Satpathy, Sashi and Martin, Richard M., Phys. Rev. Lett., **101**, p. 256801 (2008).
  - Reyren, N. et al. Superconducting interfaces between insulating oxides. Science 317, 11961199 (2007).
  - *Electric field control of the LaAlO3/SrTiO3 interface ground state* Caviglia, A. D. et al. . Nature **456**, 624627 (2008).
  - *Coexistence of magnetic order and two-dimensional superconductivity at LaAlO3/SrTiO3 interfaces*, Li, L., Richter, C., Mannhart, J. and Ashoori, R. C. . Nature Phys. **7**, 762766 (2011).
  - *Direct imaging of the coexistence of ferromagnetism and superconductivity at the LaAlO3/SrTiO3 interface*, Bert, J. A. et al. . Nature Phys. **7**, 767771 (2011).
- **April 11**: heterostructures and the metal insulator transition Description of nickelate, manganite and vanadate heterostructures. Basic concepts of Mott metal-insulator transition and their realization in multlayer structures. Orbital ordering and potential connection to topological insulators. Interfacial magnetism

  - *The metal-insulator transition and its relation to magnetic structure in (LaMnO3)2n/(SrMnO3)n superlattices*, A. Bhattacharya, S. J. May, S. G. E. te Velthuis, M. Warusawithana, X. Zhai, A. B. Shah, J.-M. Zuo, M. R. Fitzsimmons, S. D. Bader, J. N. Eckstein, Phys. Rev. Let., **100**, 257203 (2008).
  - *Probing the metal-insulator transition of NdNiO3 by electrostatic doping*, Junwoo Son, Bharat Jalan, Adam P. Kajdos, Leon Balents, S. James Allen, and Susanne Stemmer, Appl. Phys. Lett. **99**, 192107 (2011)
  - *Metal-Insulator Transition in Ultrathin $LaNiO_3$ Films* R. Scherwitzl, S. Gariglio, M. Gabay, P. Zubko, M. Gibert, and J.-M. Triscone Physical Review Letters **106**, 246403 (2011).
  - *"Topological insulators from complex orbital order in transition-metal oxide heterostructures*, A. Ruegg and G. Fiete, Phys. Rev. **B 84**, 201103 (2011).
- **April 18**: Driven systems and potential applications. Spin transfer, spin manipulation. The ac pump/current/voltage driven metal insulator transition: theory and applications.

  Suggested Reading:
  - *Mott transition field effect transistor*, D. M. Newns, J. A. Misewich, C. C. Tsuei, A Gupta, B. A. Scott and A. Schrott, Applied Physics Letters, **73** 780 (1998)
  - *Interfaces of correlated electron systems: proposed mechanism for colossal electroresistance*, Oka, T. and Nagaosa, N. Phys. Rev. Lett. **95**, 266403 (2005).
  - *Nanoscale control of an interfacial metalinsulator transition at room temperature* C. Cen, S. Thiel, G. Hammerl, C. W. Schneider, K. E. Andersen, C. S. Hellberg, J. Mannhart and J. Levy, Nature Materials **7**, 298 - 302 (2008)
  - *Electrical oscillations induced by the metal-insulator transition in VO2*, Kim H-T, Kim B-J, Choi S, Chae B-G, Lee Y W, Driscoll T, Qazilbash M M and Basov D NJ. Appl. Phys. **107** 023702 (2010)