Surfaces and Interfaces: Correlated Electron Materials

- How do the characteristic behaviors of correlated electron materials change near an interface or surface (= material/vacuum int'l)

- Many questions: device engineering → basic physics
- Ability to find answers – now within reach
- Still: more questions than answers
  more areas where the good question needs to be formulated.

Here: present questions + a few basic concepts

- These lectures: mainly transition metal oxides

~~(I) Motivating Questions + Foundational Expts~~
~~(II) The polarization catastrophe~~
~~(III) The $LaTiO_3/SrTiO_3$ heterostructure~~
~~(IV) Colossal Magnetoresistance~~
~~(V) Prospects~~

(I) The Questions
(II) Some motivating experiments
(III) Theory polarization catastrophe
(IV) Theory
(V) The $LaTiO_3/SrTiO_3$ heterostructure
(VI) CMR heterostructures
(VII) Prospects

The Questions

- Correlated electron materials: CTMO
  - $La_{2-x}Sr_xCuO_4$ - high T_c
  - $La_{1-x}Sr_xMnO_3$ - "half metal" (pol. cond. band)
    - charge, orbital, mag. order
    - "colossal" MR + other enhanced respons
  - V_2O_3 - metal insulator transition

General: "exotic" electronic phases
enhanced response

~~Q: how does this change near an interface~~
~~Both academic and practical relevance~~

Physics: d-orbital. Starts 5x degen.
⇒ can hold 10 el.

- + physics strongly affected by
  - ~~Carrier density~~
  - Interaction effects: - $U_{dd} = E(N+1) + E(N-1) - 2E(N)$
    - Hund coupling (max spin state)
  - Ligand Field [split d-levels] ⇔ lattice
  - Hybridization (electron itinerancy)
  - Carrier density

In many materials, different states close by in energy are finely balanced
⇒ even small changes ⇒ big difference

- What is different about surface/interface
  - Surface: lower coordination (1 direction electrons can't go)
  - Different interaction. [U dep. on environment] - Sawatzky
  - Different crystal symmetry (typically lower)

Rules of thumb:
- lower coordination: less KE ⇒ more ins
- vacuum: less screening ⇒ larger U
- lower sym: less fluct., easier to localize.

⇒ CVO prl.
⇒ moore PRL

- Question not just academic

$3(1-x) + 2(x) - 6 + [V_m] = 0 \Rightarrow V_m = 3+x$
$\Rightarrow n_d = 4-x$

$La_{1-x}Sr_xMnO_3$: Mn: ≈ cubic environment
$= e_g$ x^2-y^2 $3z^2-r^2$

⇒ 5 Mn d: $= t_{2g}$ (d_{xy}, d_{xz}, d_{yz})

Interactions such that $4-x$ d e^-/Mn
3 in t_{2g}, max spin state
$(1-x)$ in e_g. Spin "slaved" to t_{2g} "core" spin.