

Surfaces and Interfaces Involving Correlated Electron Materials (mainly transition metal oxides)

A. J. Millis

Department of Physics
Columbia University



Collaborators

S. Okamoto (CU, now ORNL)

Claude Ederer (CU, now Trinity, Dublin)

P. Werner (CU->Zurich)

****Chungwei Lin (CU)****

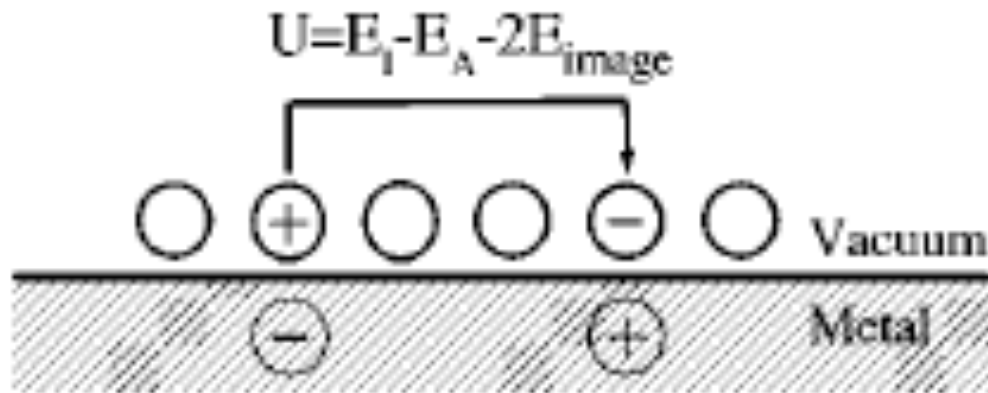
Support: DOE ER-46169, CU MRSEC



Different Interaction at Surface

Duffy and Stoneham J. Phys. C16 4087 (1983)

Altieri...Sawatzky PRB 59 2517 (1999)

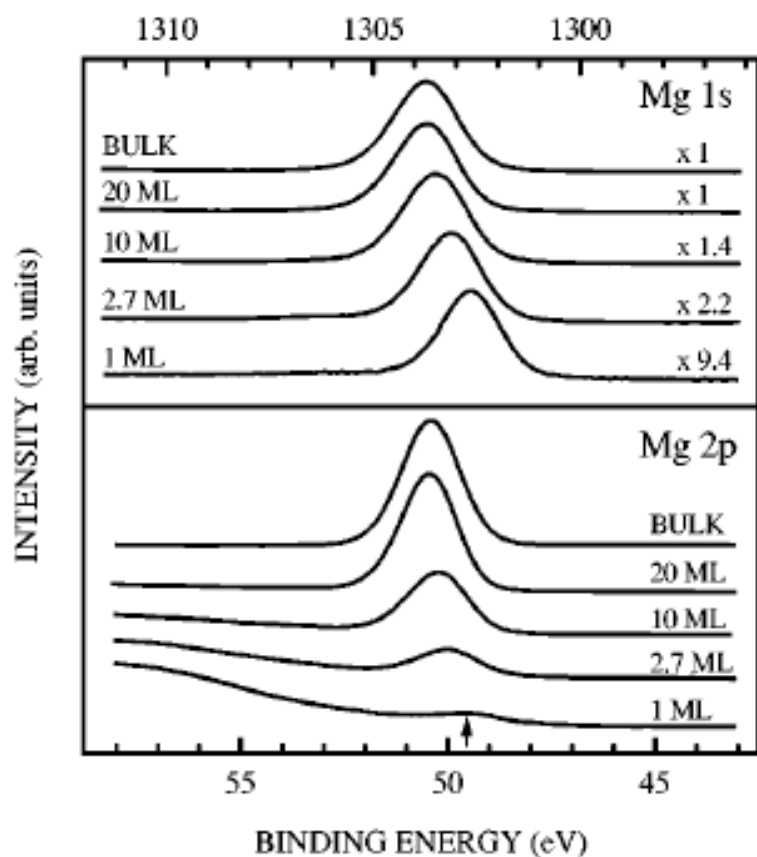


$U = E_2 + E_0 - 2E_1$ **reduced** by image charges in polarizable medium

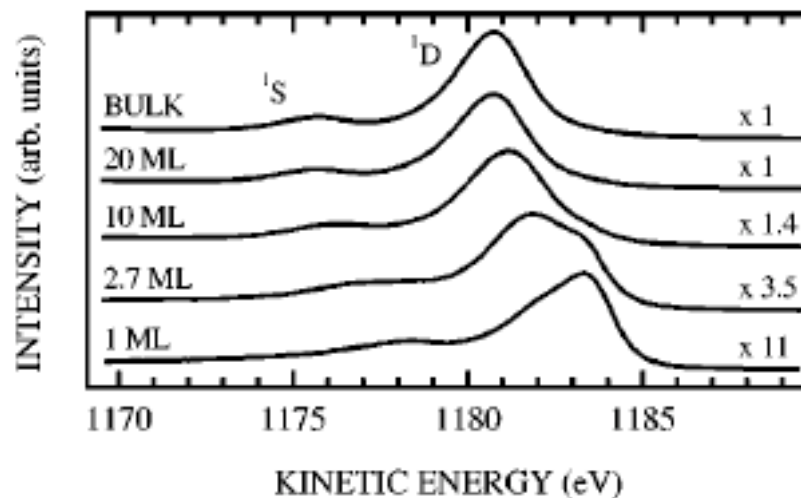


Different Interaction at Surface

Altieri...Sawatzky PRB 59 2517 (1999)



Auger



S-D multiplet splitting unchanged

	1 ML	2.7 ML	10 ML	20 ML	Bulk
$U(\text{Mg } 2p(^1D))$	20.3	21.3	21.7	22.1	22.1
$\delta U(\text{Mg } 2p)$	-1.8	-0.8	-0.4	0	0
$\delta \Delta(\text{O } 2p \rightarrow \text{Mg } 3s)$	-2.5	-1.2	-0.5	0	0



Department of Physics
Columbia University

Surface differs from bulk II

Photoemission

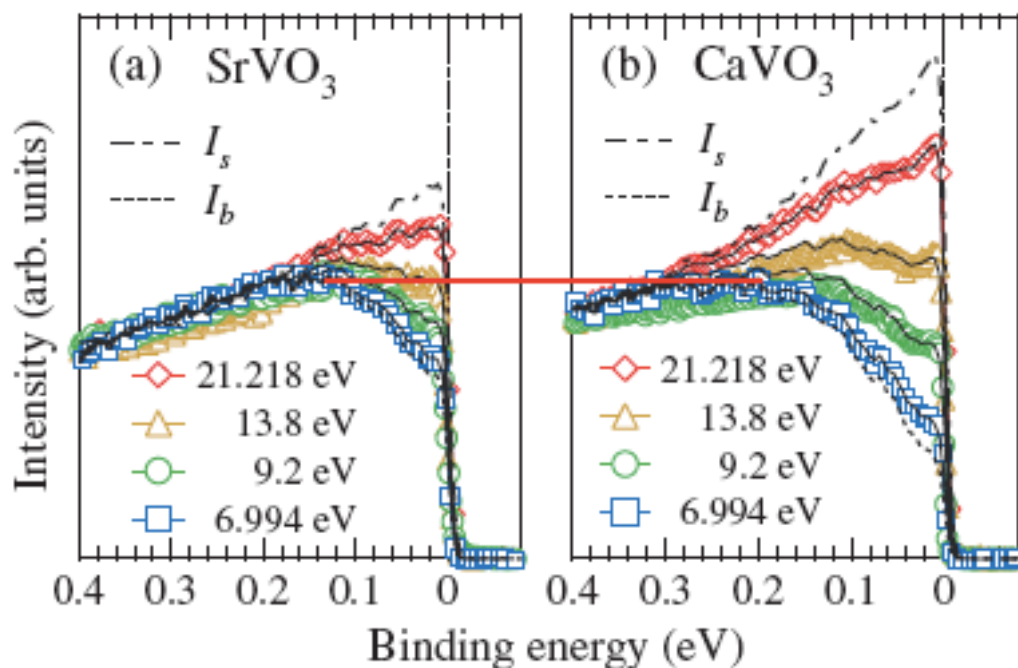
PRL 96, 076402 (2006)

PHYSICAL REVIEW LETTERS

week ending
24 FEBRUARY 2006

Bulk- and Surface-Sensitive High-Resolution Photoemission Study of Two Mott-Hubbard Systems: SrVO_3 and CaVO_3

R. Eguchi,^{1,2} T. Kiss,¹ S. Tsuda,¹ T. Shimojima,¹ T. Mizokami,¹ T. Yokoya,¹ A. Chainani,² S. Shin,^{1,2} I. H. Inoue,³ T. Togashi,² S. Watanabe,¹ C. Q. Zhang,⁴ C. T. Chen,⁴ M. Arita,⁵ K. Shimada,⁵ H. Namatame,⁵ and M. Taniguchi^{5,6}



**Lower photon energy:
more bulk sensitive.**

**More surface DOS
=> surface is metallic
although bulk is
insulating**



Department of Physics
Columbia University

Surface different from Bulk: III

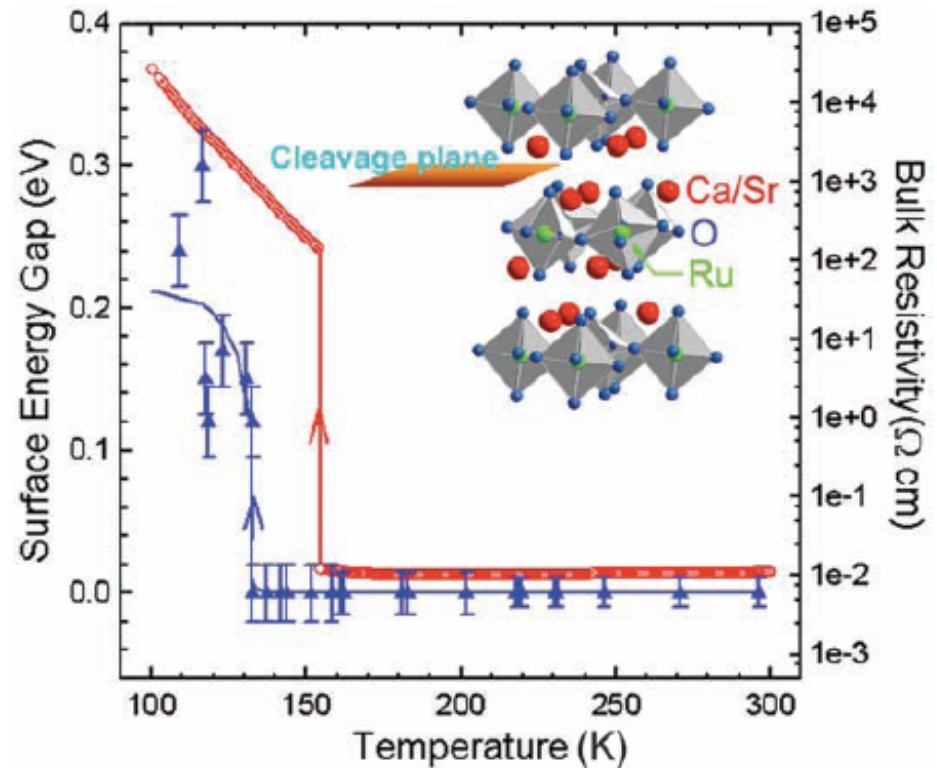
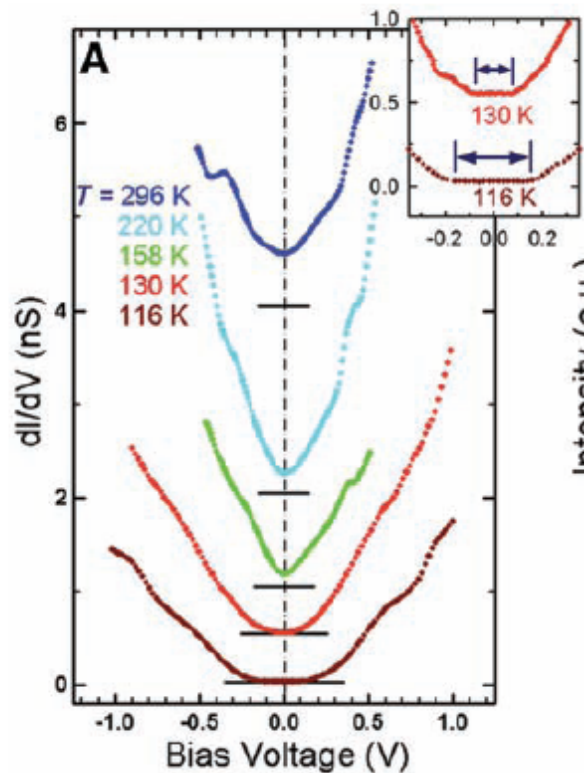
A Surface-Tailored, Purely Electronic, Mott Metal-to-Insulator Transition

R. G. Moore,¹ Jiandi Zhang,^{2,3} V. B. Nascimento,¹ R. Jin,³ Jiandong Guo,¹
G.T. Wang,⁴ Z. Fang,⁴ D. Mandrus,³ E. W. Plummer^{1,3}

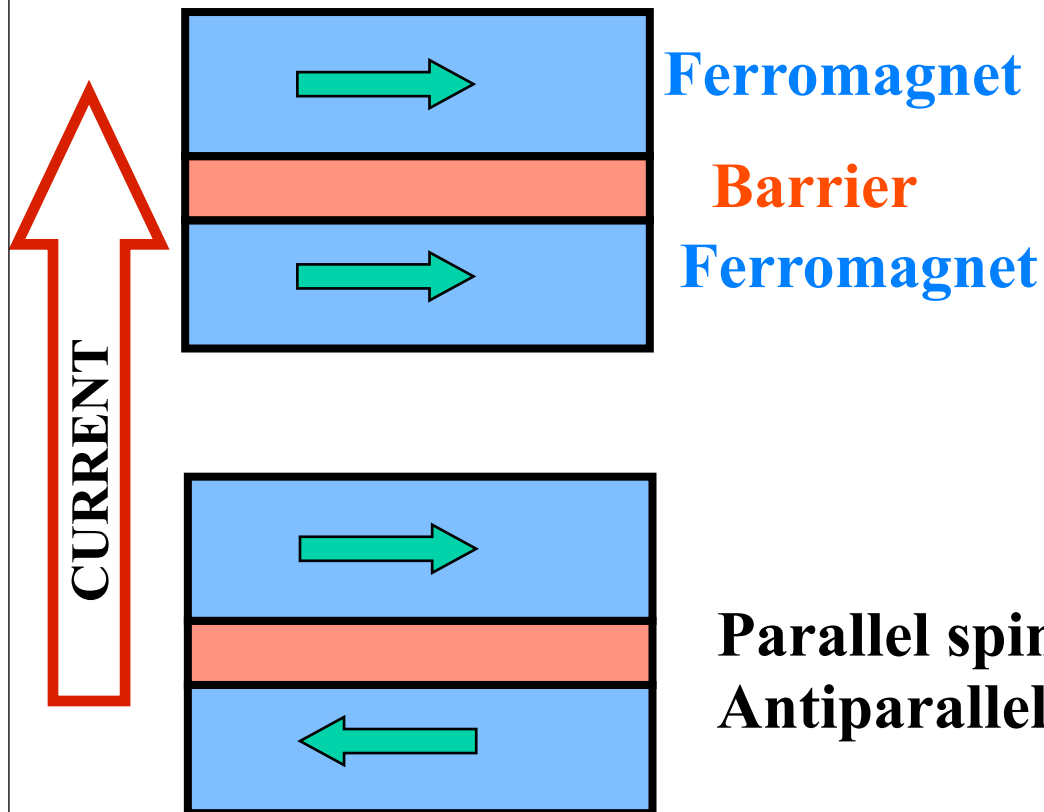
SCIENCE VOL 318 26 OCTOBER 2007

Surface-bulk difference attributed to lattice effects

615



'Spin Valve'



Device properties controlled by many body physics (here, magnetism) at the interface

Parallel spin: more current
Antiparallel spin: less current

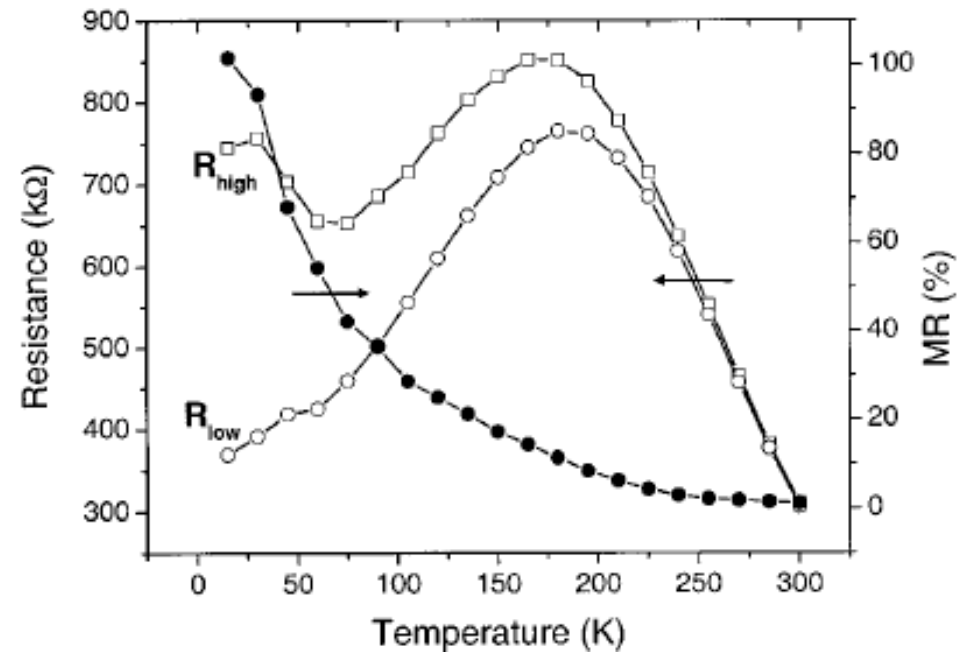
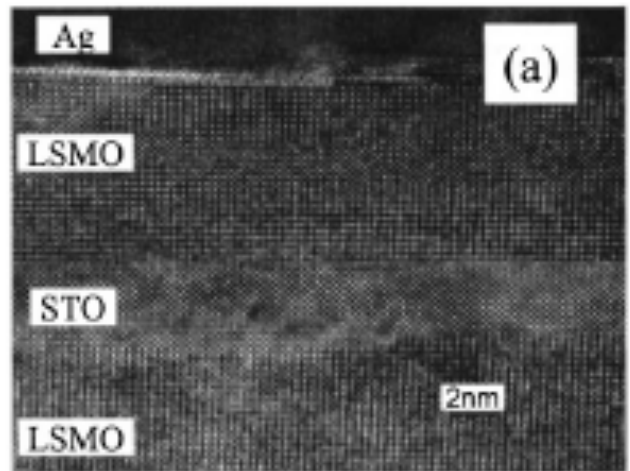


CMR spin valve

Noh, Nath, Eom, Sun....
APL 79 233 (2001)

Device dies by 100K
although $T_c \sim 350K$

TEM of Device



Something new happens at interface



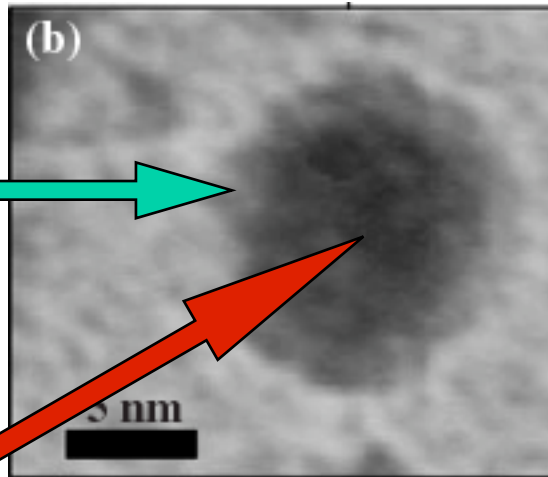
Department of Physics
Columbia University

Motivation II: Nanoparticles

Example: $\text{Co}_{80}\text{Ni}_{20}$

TEM:

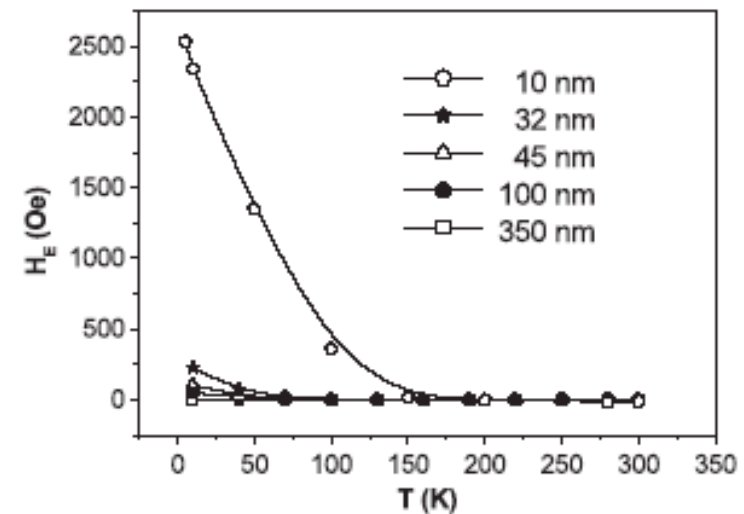
**“Skin”: AF
Co Oxide**



**Core: FM
Co-Ni metal**

Luna et al, Nanotechnology
15, S293 (2004)

**Claim: for small particles,
AF “skin” => exchange field**



Simple messages:

--”skin” different from core

--interplay=>interesting properties

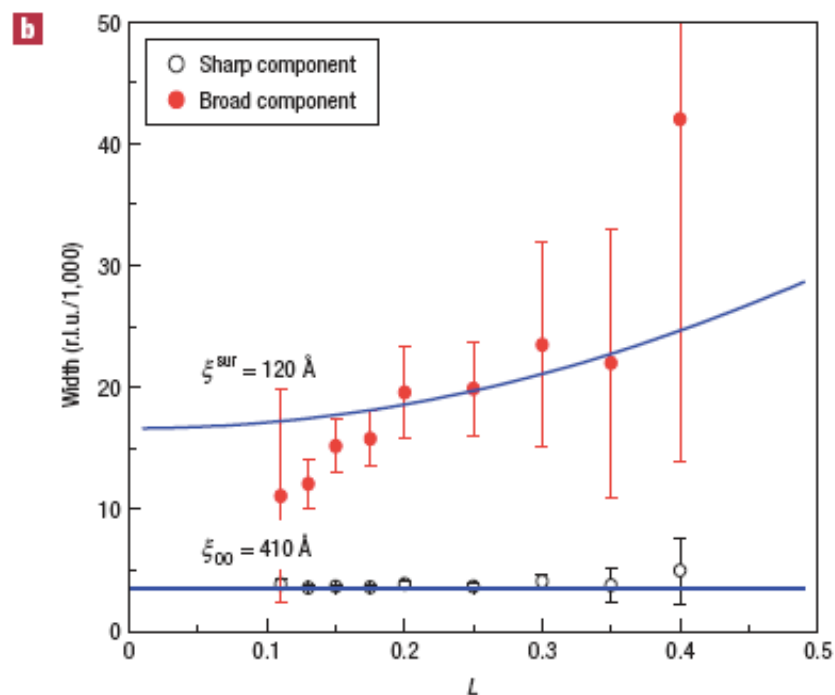
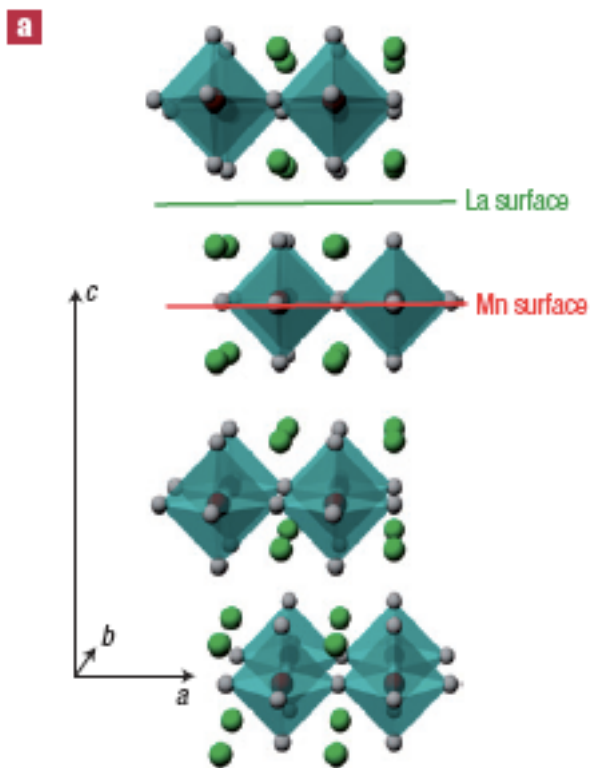


Department of Physics
Columbia University

Surface Differs from Bulk: Resonant X-Ray scattering

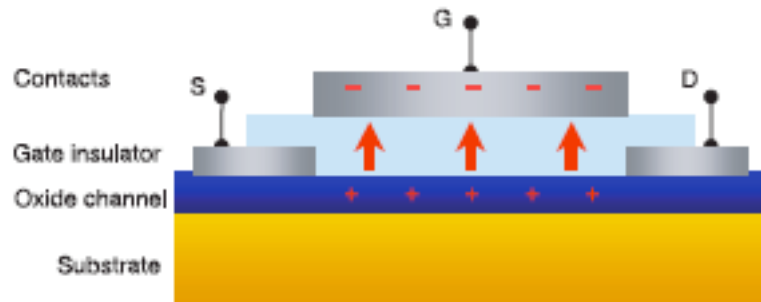
Surface effects on the orbital order in the single-layered manganite $\text{La}_{0.5}\text{Sr}_{1.5}\text{MnO}_4$

Y. WAKABAYASHI^{1,2*}, M. H. UPTON², S. GRENIER^{2,3}, J. P. HILL², C. S. NELSON⁴, J.-W. KIM⁵, P. J. RYAN⁵, A. I. GOLDMAN⁵, H. ZHENG⁶ AND J. F. MITCHELL⁶



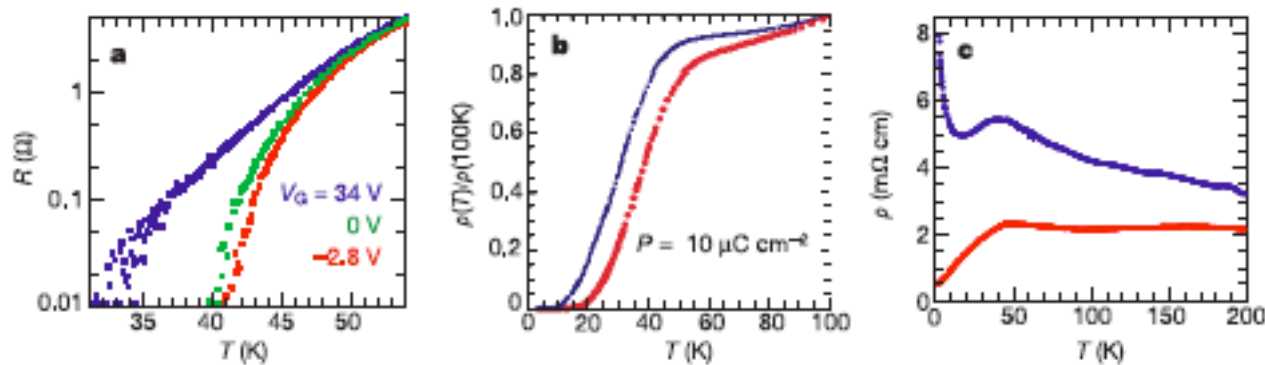
Electric field doping

(Triscone and Ahn, Nature 424 1015 2004)



Natural questions:

- what really happens at interface??
- how much doping can you get??



?New Phenomena?

S. Parkin: what interface do I have to make to get an electron gas which superconducts at room temperature??



“Material by design”

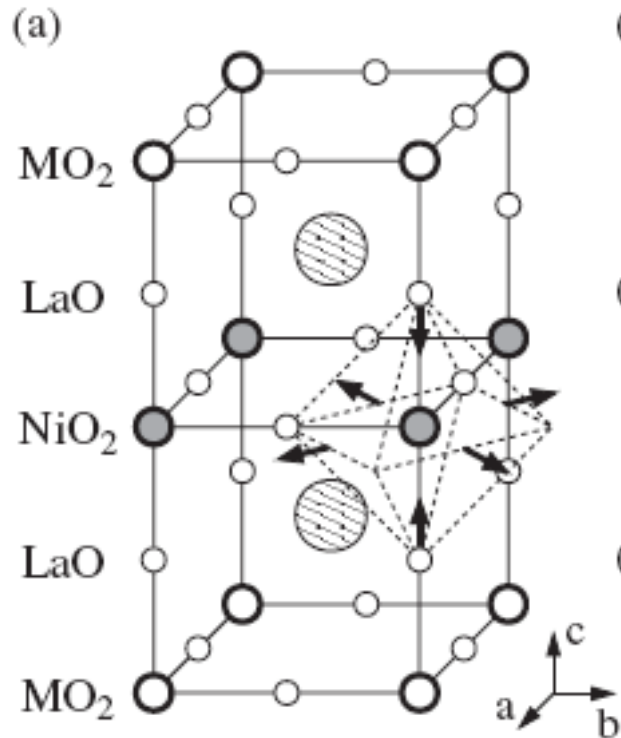
PRL 100, 016404 (2008)

PHYSICAL REVIEW LETTERS

week ending
11 JANUARY 2008

Orbital Order and Possible Superconductivity in $\text{LaNiO}_3/\text{LaMO}_3$ Superlattices

Jiří Chaloupka^{1,2} and Giniyat Khaliullin¹



**Symmetry breaking from
superlattice picks out $d_{x^2-y^2}$
orbital \Rightarrow high T_c**

