Superconductivity at $LaTiO_3/SrTiO_3$ interface

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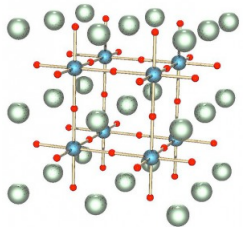
Biscaras et al arXiv:1002.3737

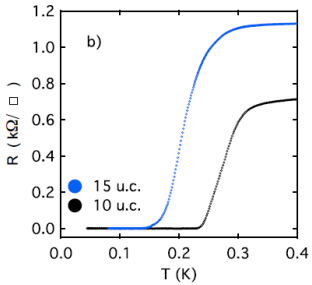
Outline

Antiferromagnet Mott Insulator $LaTiO_3$

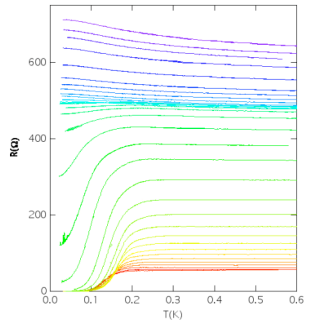


Homometallic interface : $LaTiO_3/SrTiO_3$

2DEG superconducting gas



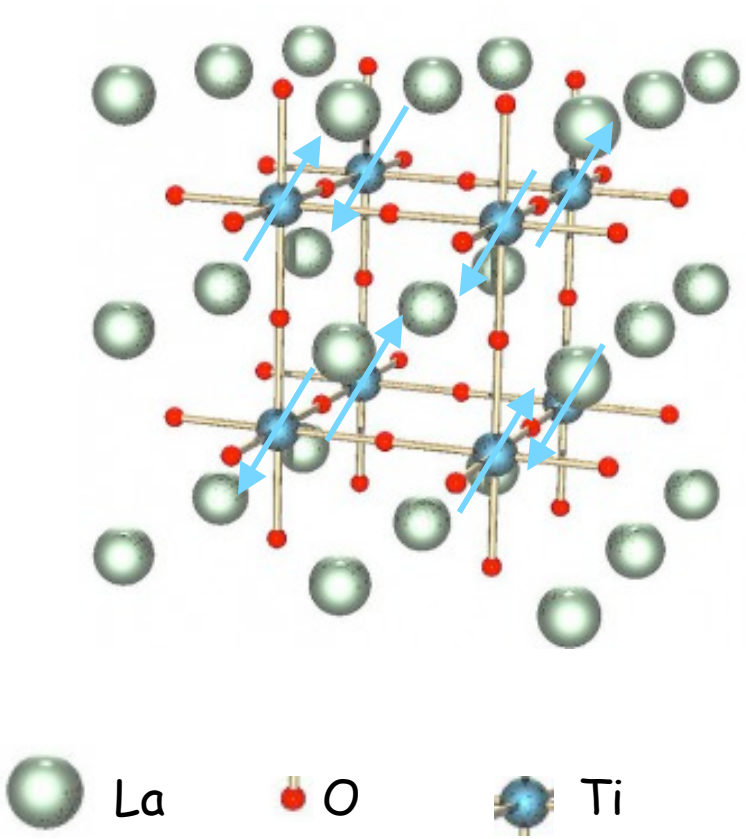
Physics of the $LaTiO_3/SrTiO_3$ interface

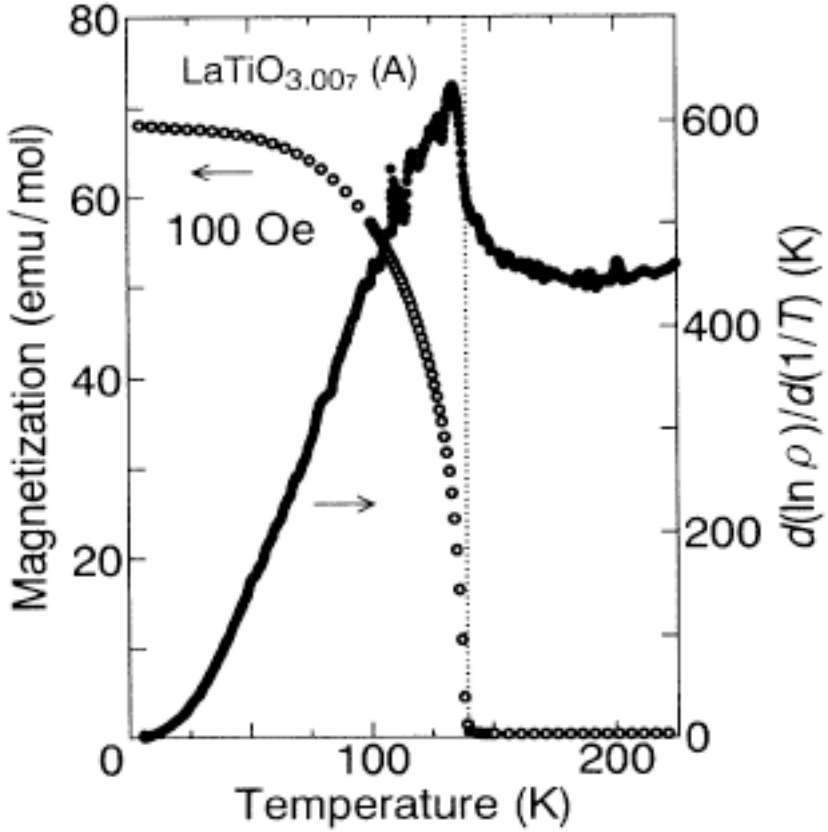


Conclusions

Antiferromagnet Mott Insulator $LaTiO_3$

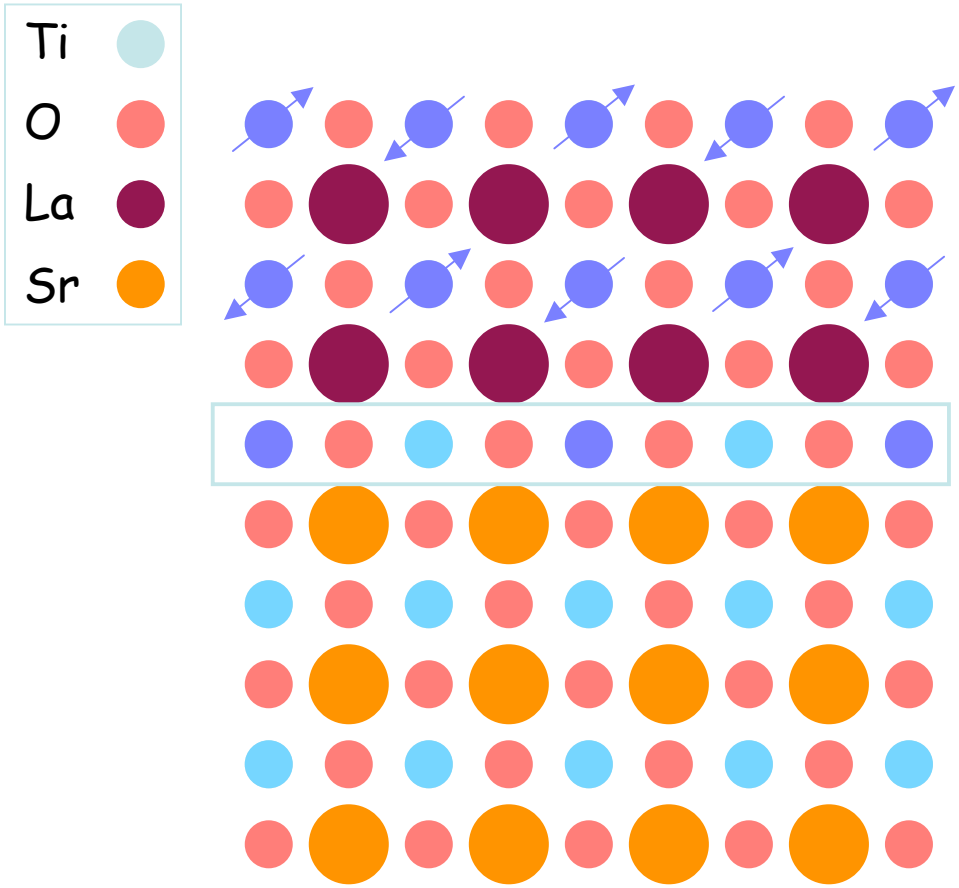
Pseudocubic Perovskite a = 3.928 Å
Ti 3^+ : $3d^1$ configuration
Spin 1/2 : Mott Antiferromagnet : T_N = 120 K





Okada et al PRB 1993

Homometallic interface : $LaTiO_3/SrTiO_3$



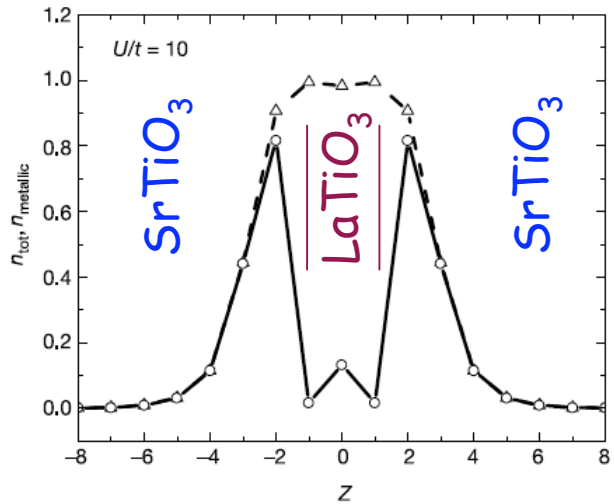
Ti 3+ $3d^1$

Ti 4+ $3d^0$

$LaTiO_3$ Mott Insulator

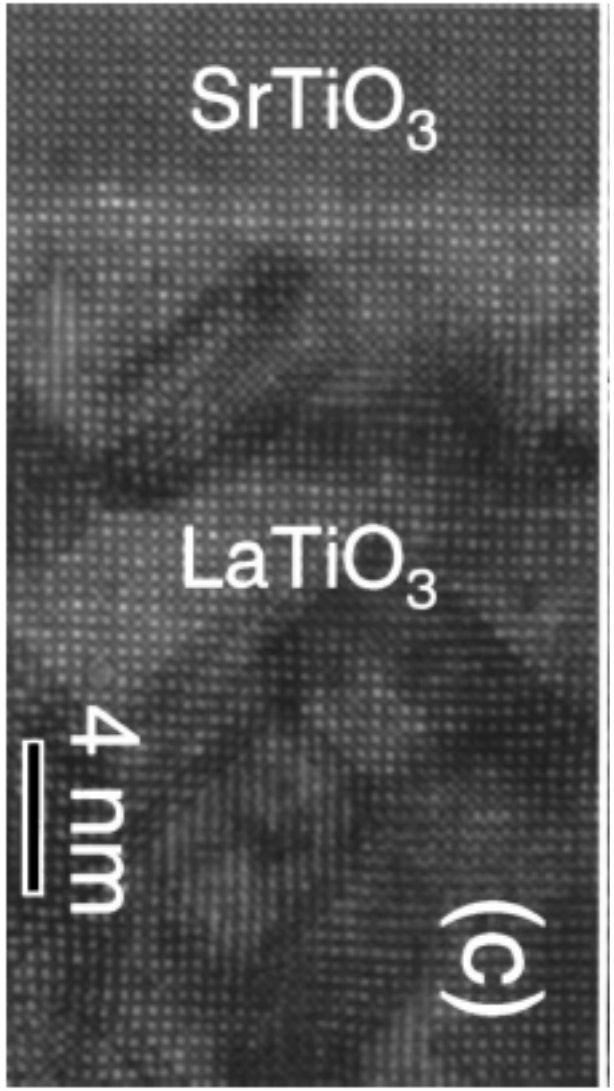
2 DEG $3.\ 10^{14}\ /cm^2$

$SrTiO_3$ Band Insulator

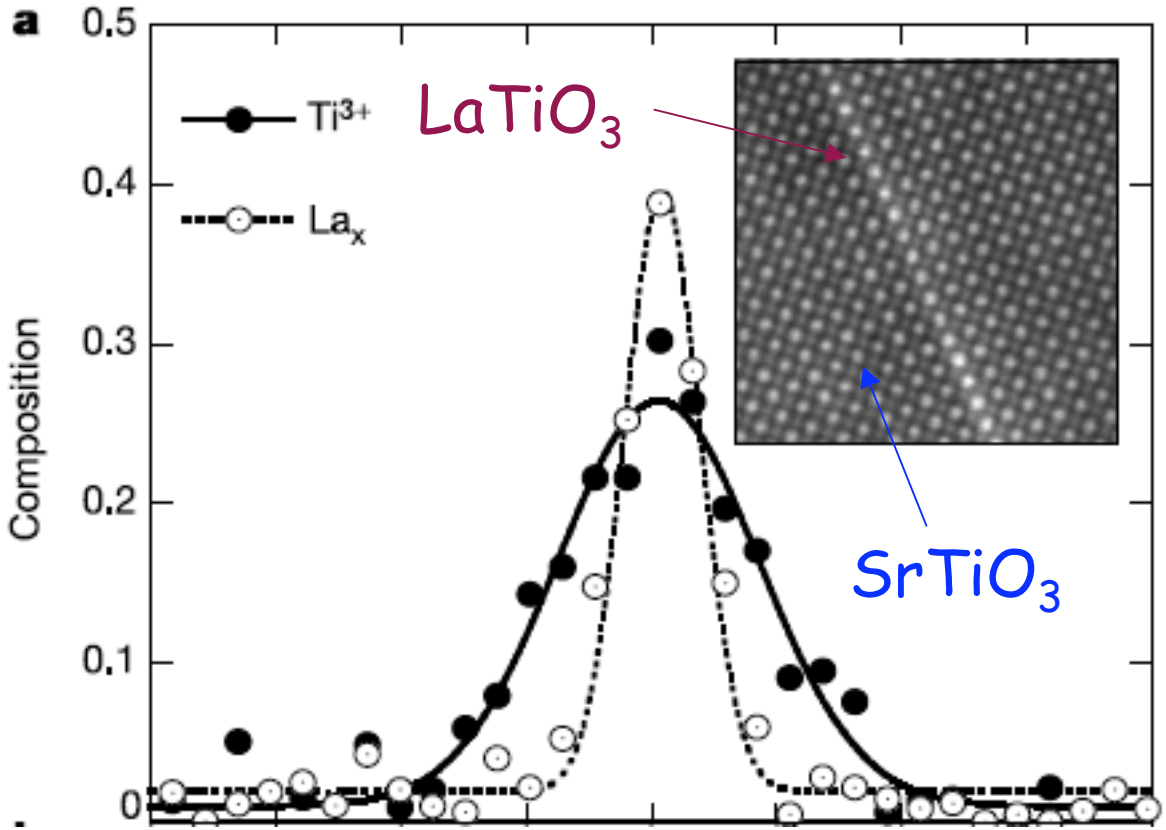


Okamoto et al Nature 2004

Homometallic interface : $LaTiO_3/SrTiO_3$



Ohtomo et al APL 2002

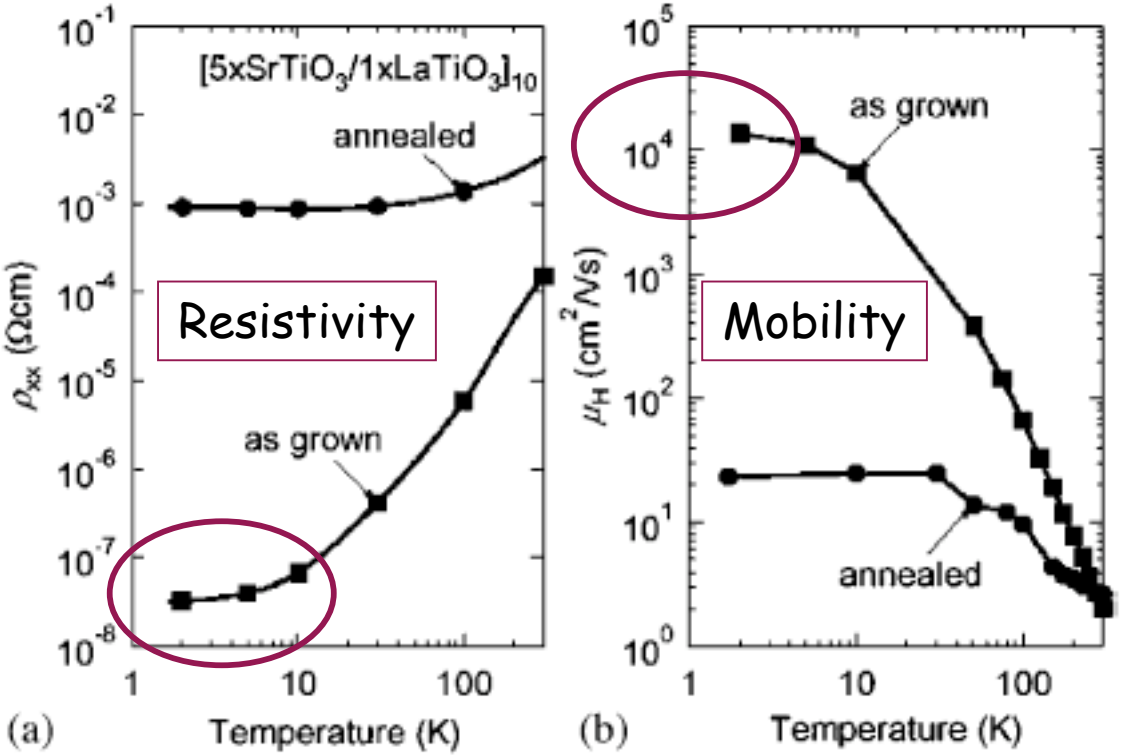


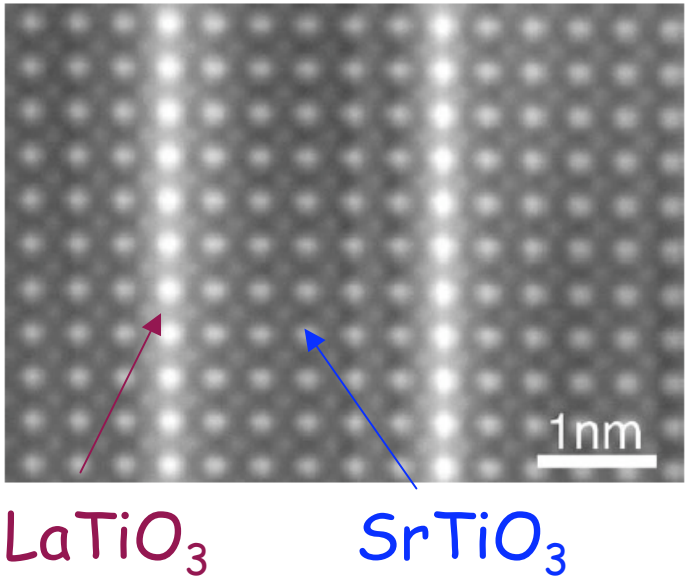
Ohtomo et al Nature 2002

Spread of the electrons within $SrTiO_3$

Homometallic interface : $LaTiO_3/SrTiO_3$

Superlattices

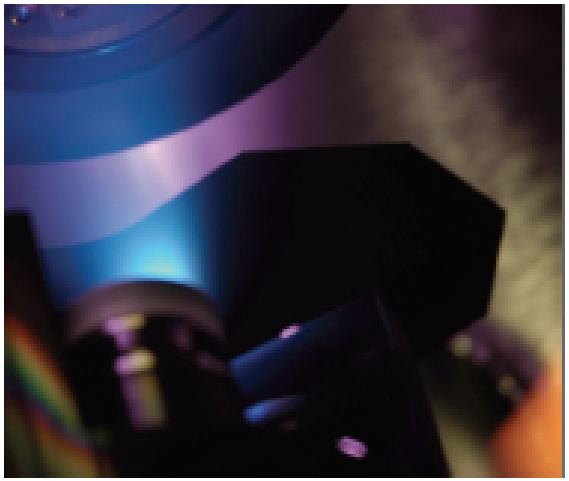




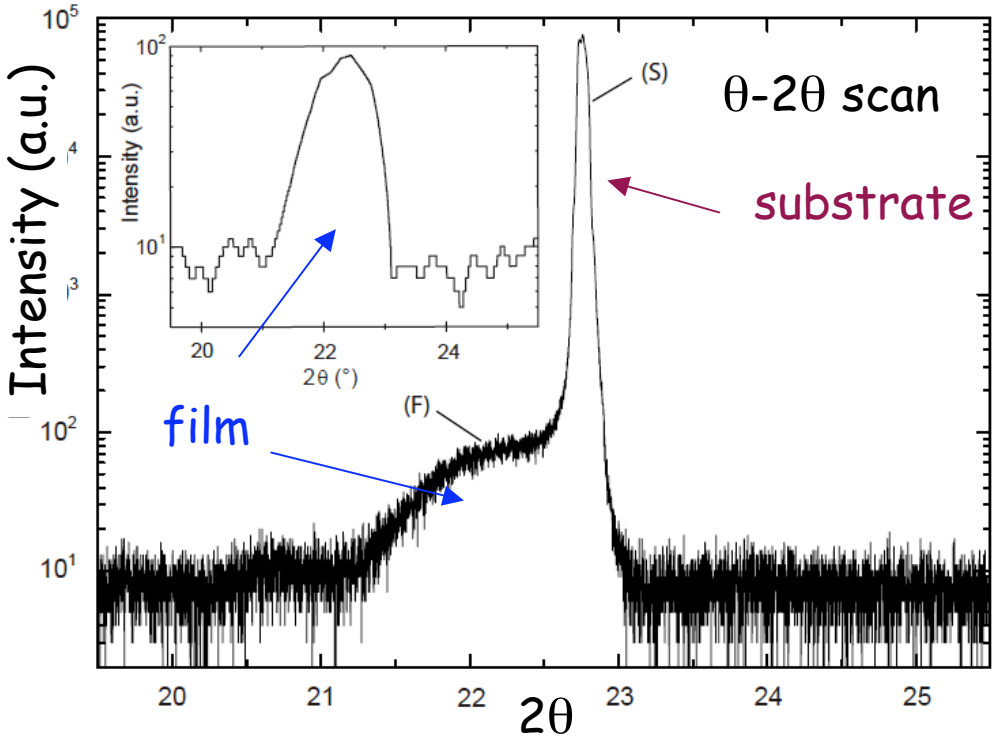
Hwang et al Physica E 2004

High mobility 2DEG : $\mu = 10^4$ cm²/Vs : metallic behavior

Growth of the $LaTiO_3/SrTiO_3$ layer



Pulsed Laser Deposition (100) $SrTiO_3$



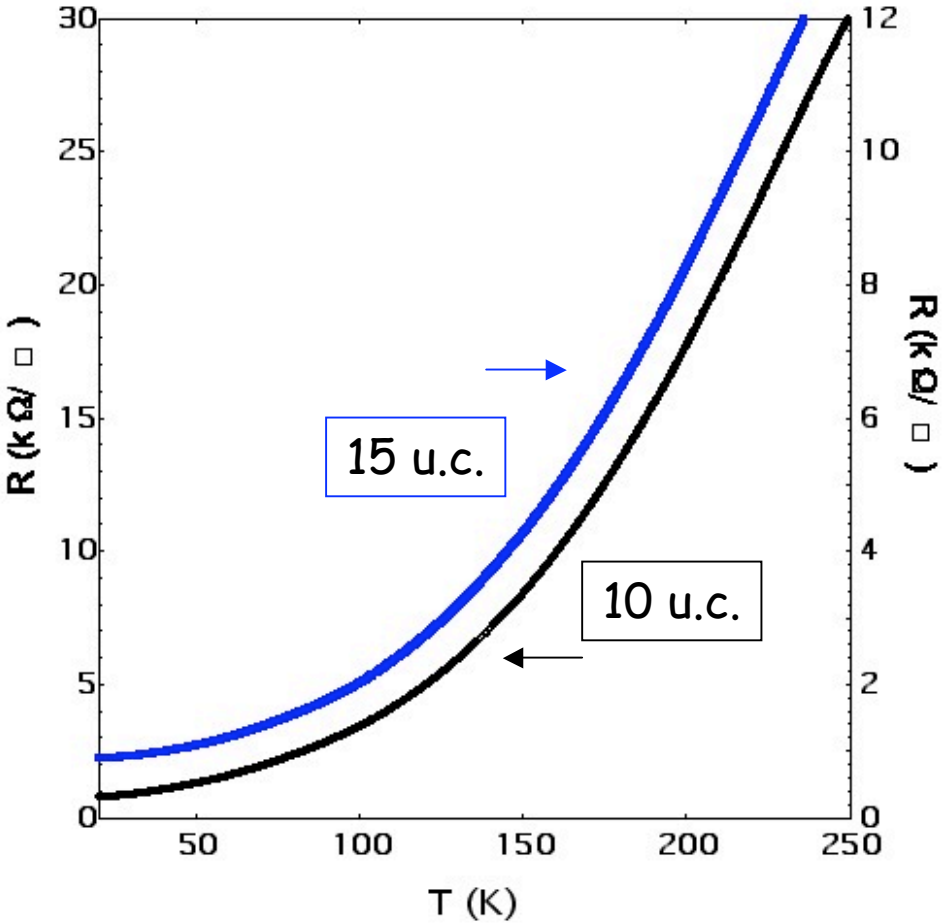
Surface reconstruction — Temperature 850°C-950°C. Pressure 200 mT O_2. 1 hour

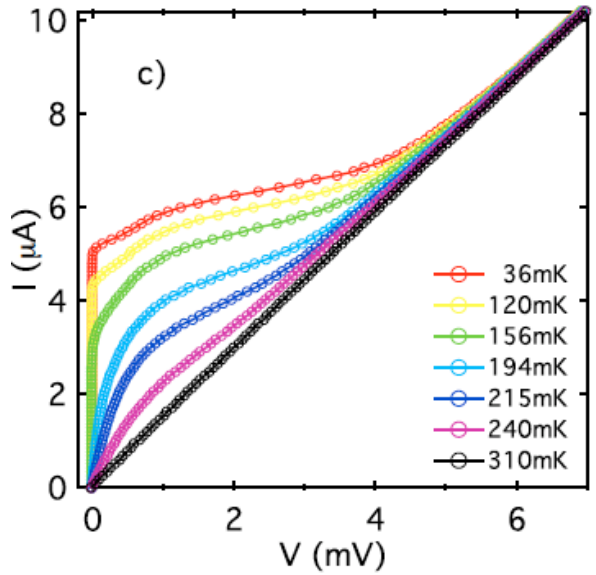
Growth — 1. 10^{-4} torr oxygen. 1 J/cm²/pulse at 3Hz . 0.12 Å/s

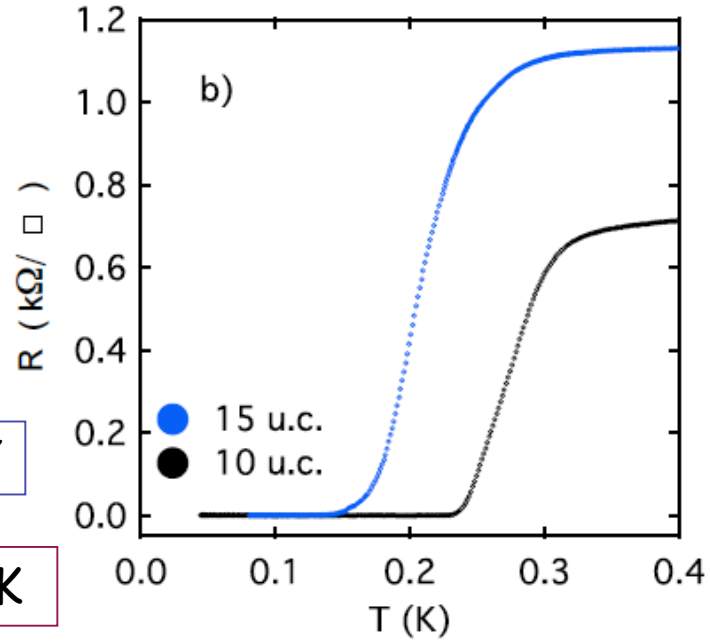
Samples — From 5 to 20 u.c. — (100) Oriented $LaTiO_3$ a = 3.95 Å

Superconducting interface : $LaTiO_3/SrTiO_3$

(100) Oriented $LaTiO_3/SrTiO_3$







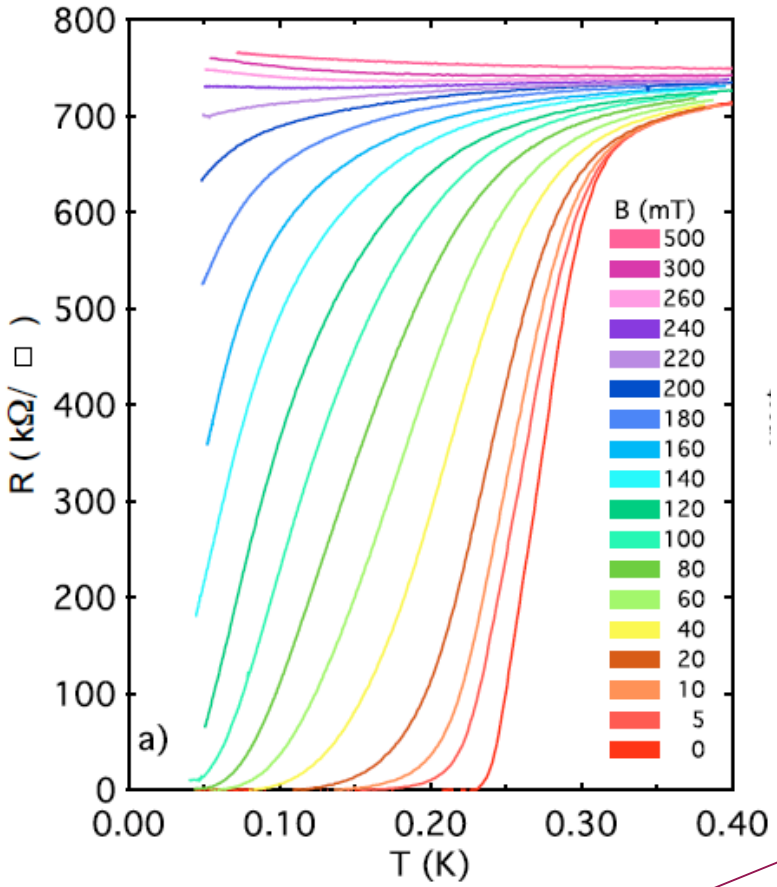
Metallic behavior

Biscaras et al arXiv:1002.3737

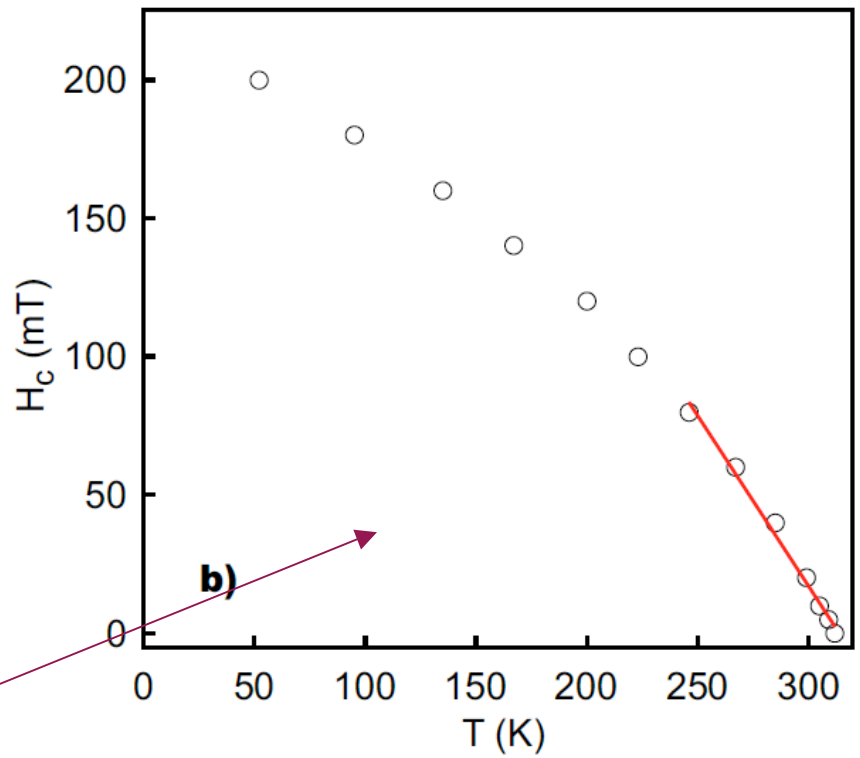
Superconductivity at 250-300 mK

2D Superconducting layer

10 u.c. $LaTiO_3/SrTiO_3$



Perpendicular field



$$H_\perp(T) = \frac{\phi_0}{2\pi\xi_{//}^2(T)}$$

$$H_{//}(T) = \frac{\sqrt{3}\phi_0}{\pi d\,\xi_{//}(T)}$$

$$\xi_{//}(T) \propto (T - T_c)^{-1/2}$$

$$\xi_{//}(T=0) = 36nm$$

$$H_\perp(T=0) = 240mT$$

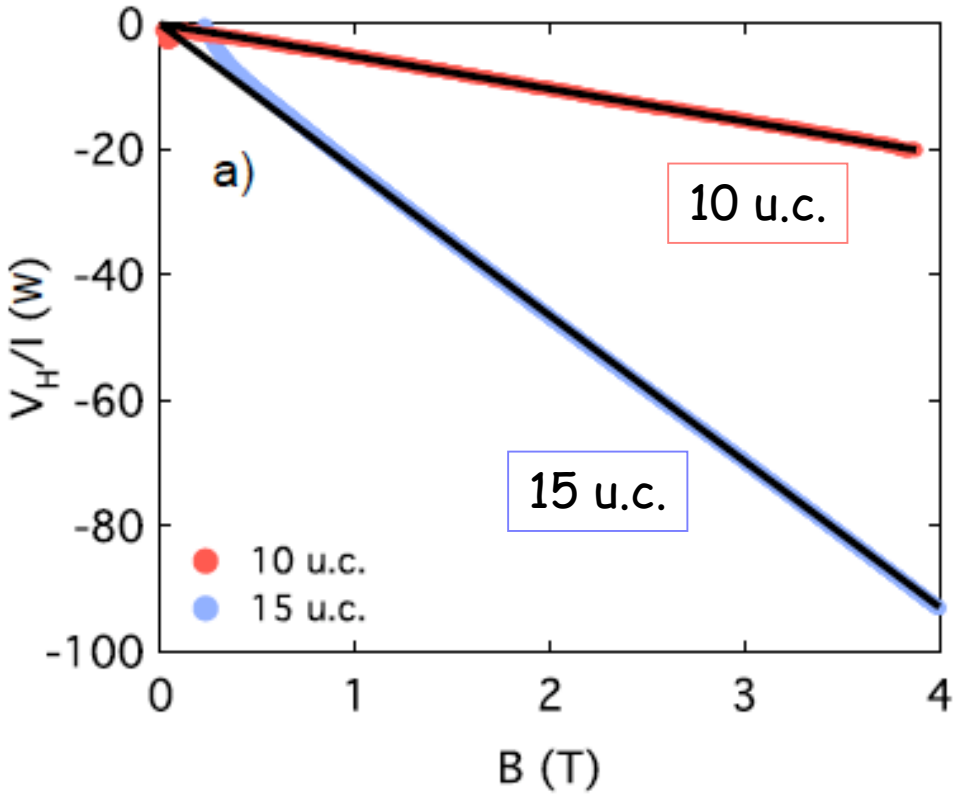
$$H_{//}(T=0) = 2.3T$$

$$d \le 11nm$$

$$2DEG$$

Mobility and sheet density

$LaTiO_3/SrTiO_3$

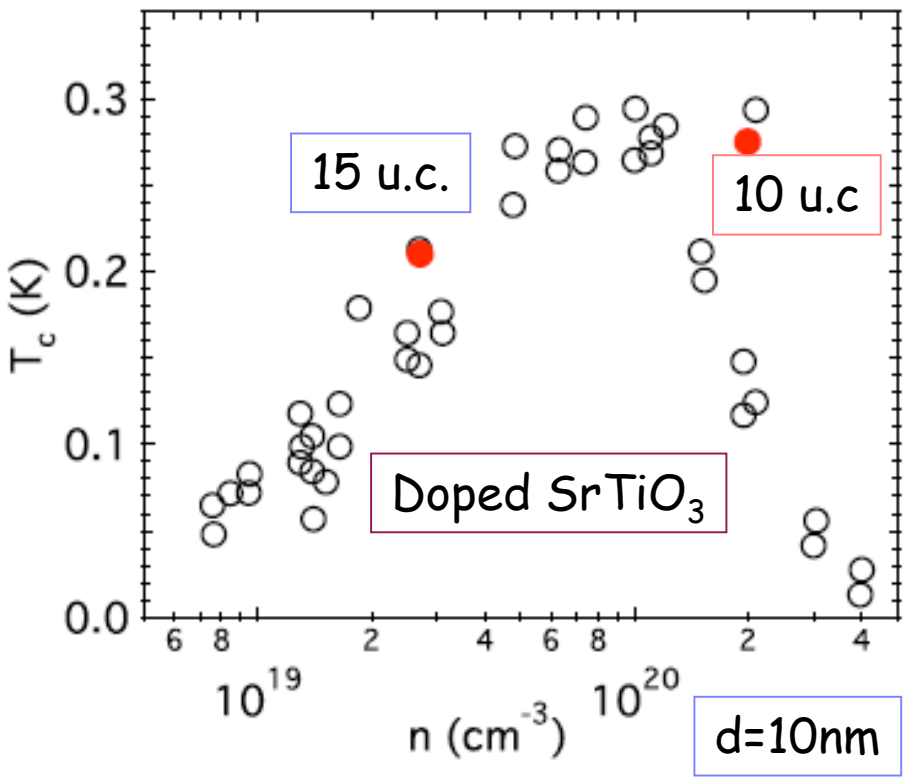


Mobility μ = 210 cm^2/Vs
Sheet density n = 2 10^{14} $/cm^2$

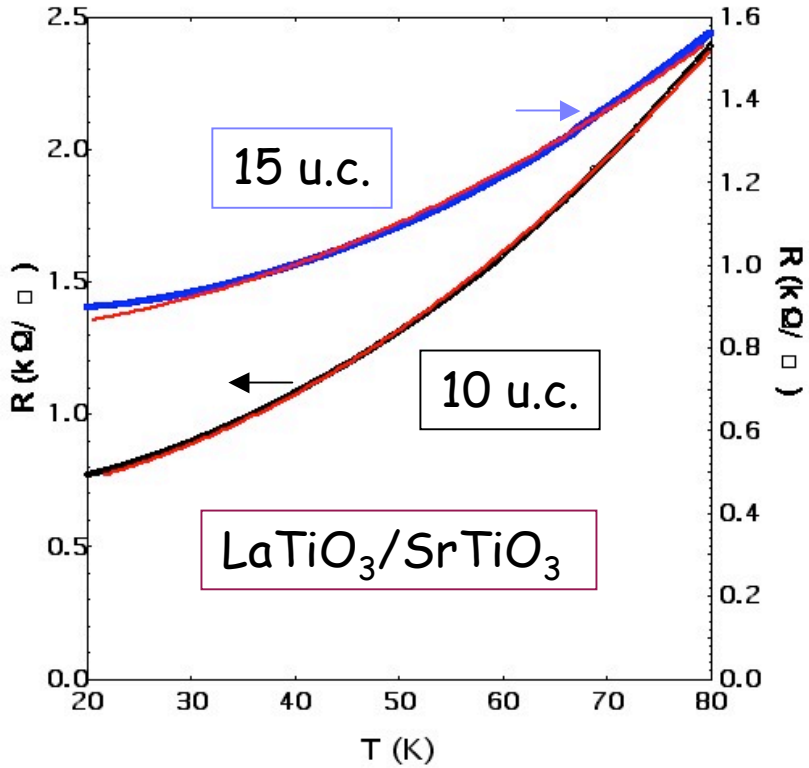
Mobility μ = 50 cm^2/Vs
Sheet density n = 2.7 10^{13} $/cm^2$

Biscaras et al arXiv:1002.3737

What is superconducting ?



Koonce et al Phys; Rev. 1967



$R = R_0 + AT^2$

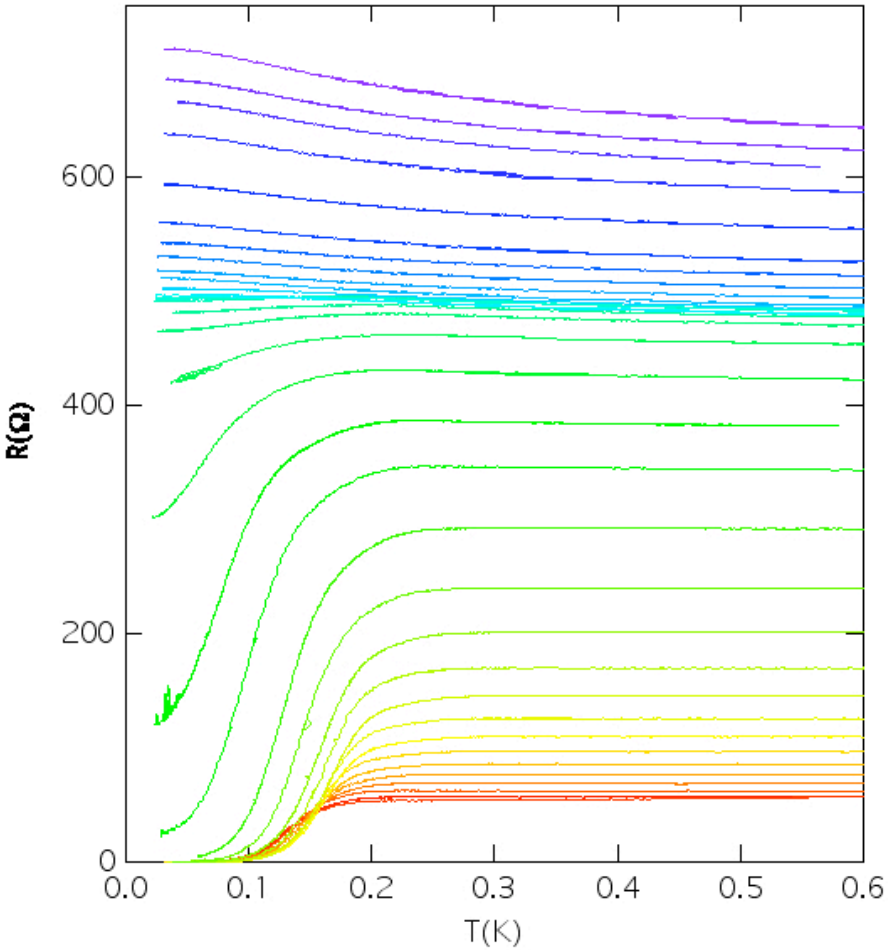
O or Sr doped $LaTiO_3$: $A = 10^{-9}$ range
Vac. or La doped $SrTiO_3$: $A = 10^{-7}$ range

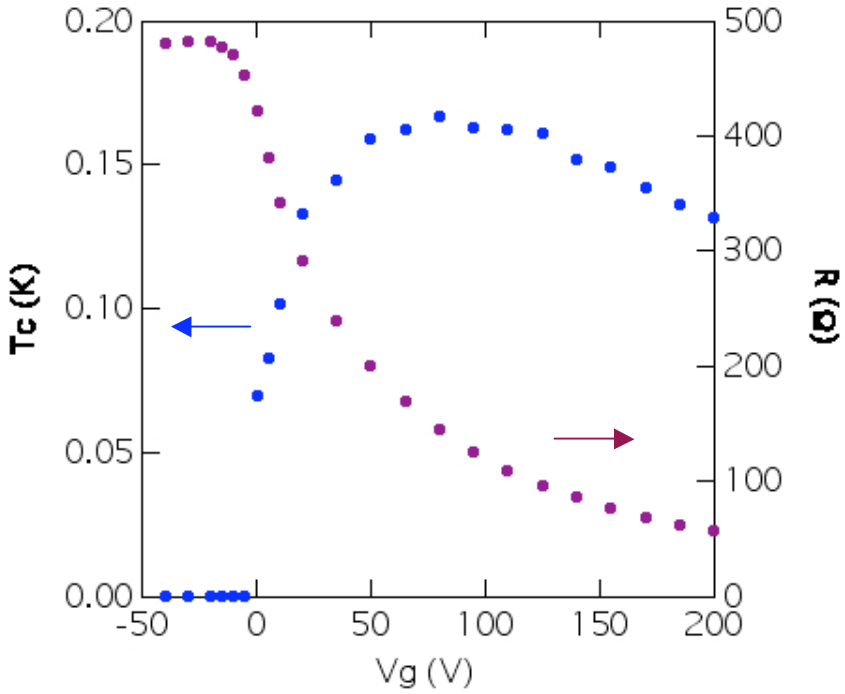
A(10 u.c.) = $2.7\ 10^{-7}$
A(15 u.c.) = $1.1\ 10^{-7}$

Electric field effect

15 u.c.

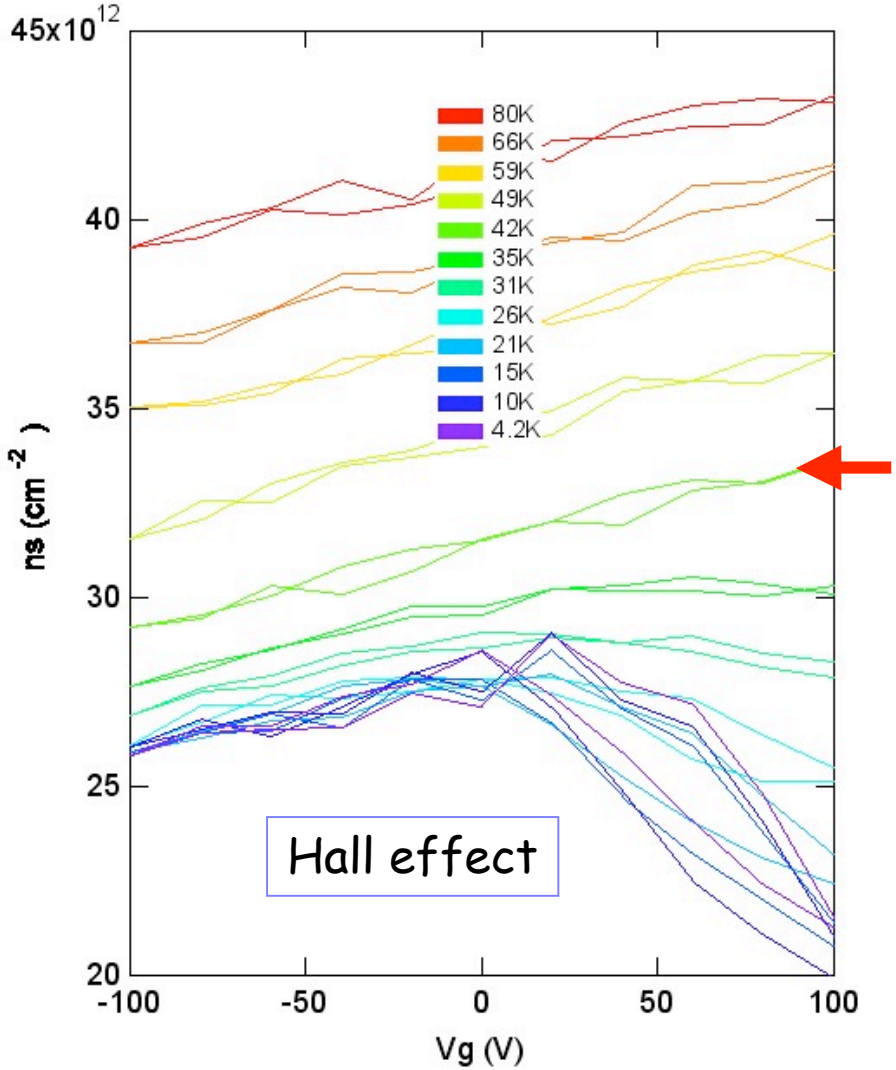
Superconductor-Insulator transition

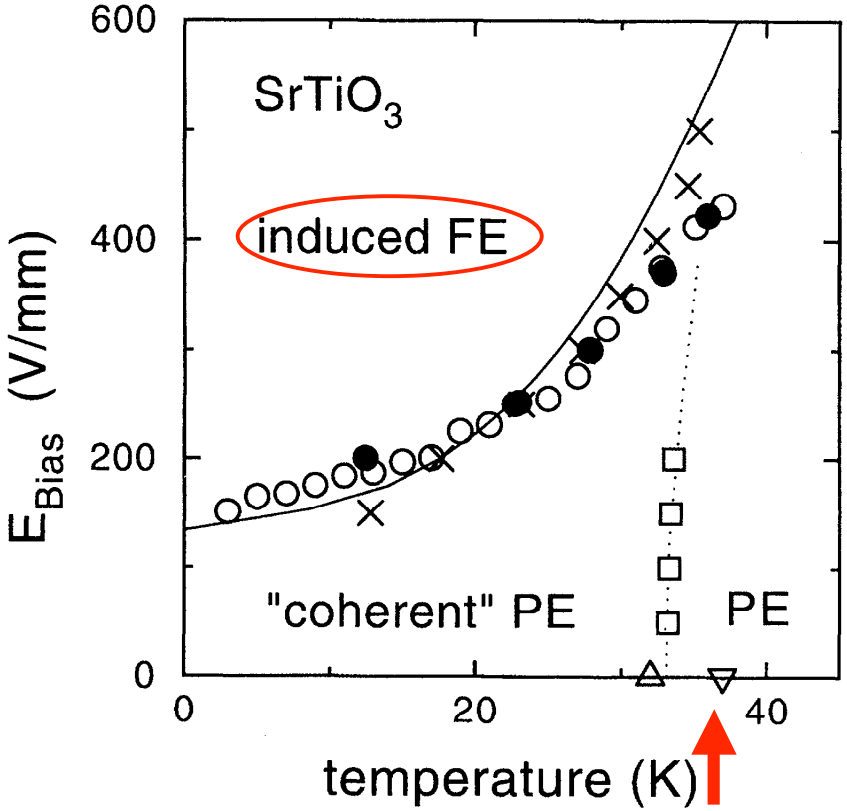




Superconducting dome

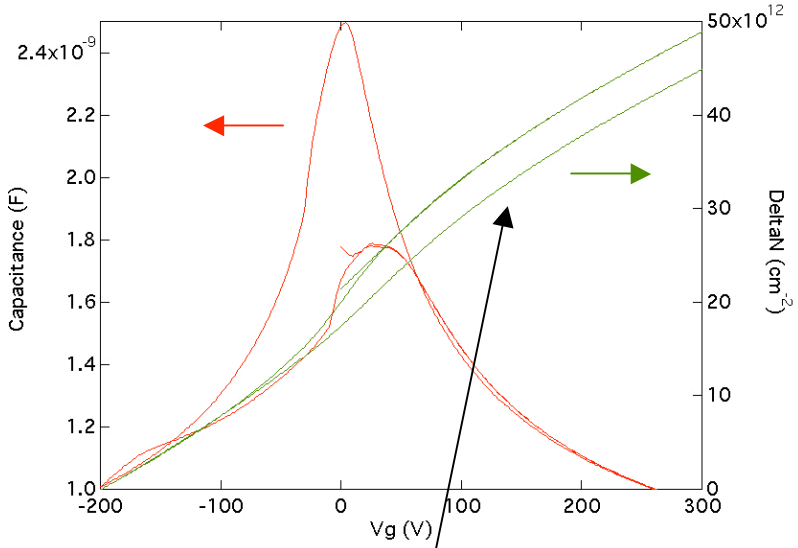
Hysteretic behavior : $SrTiO_3$ property

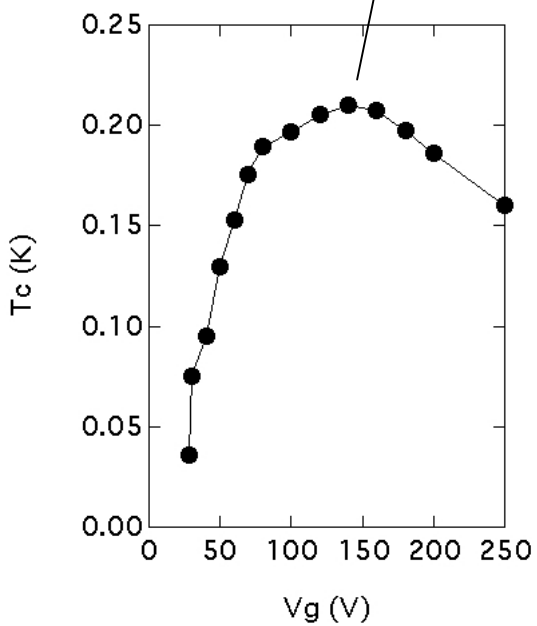




Hemberger et al PRB 1995

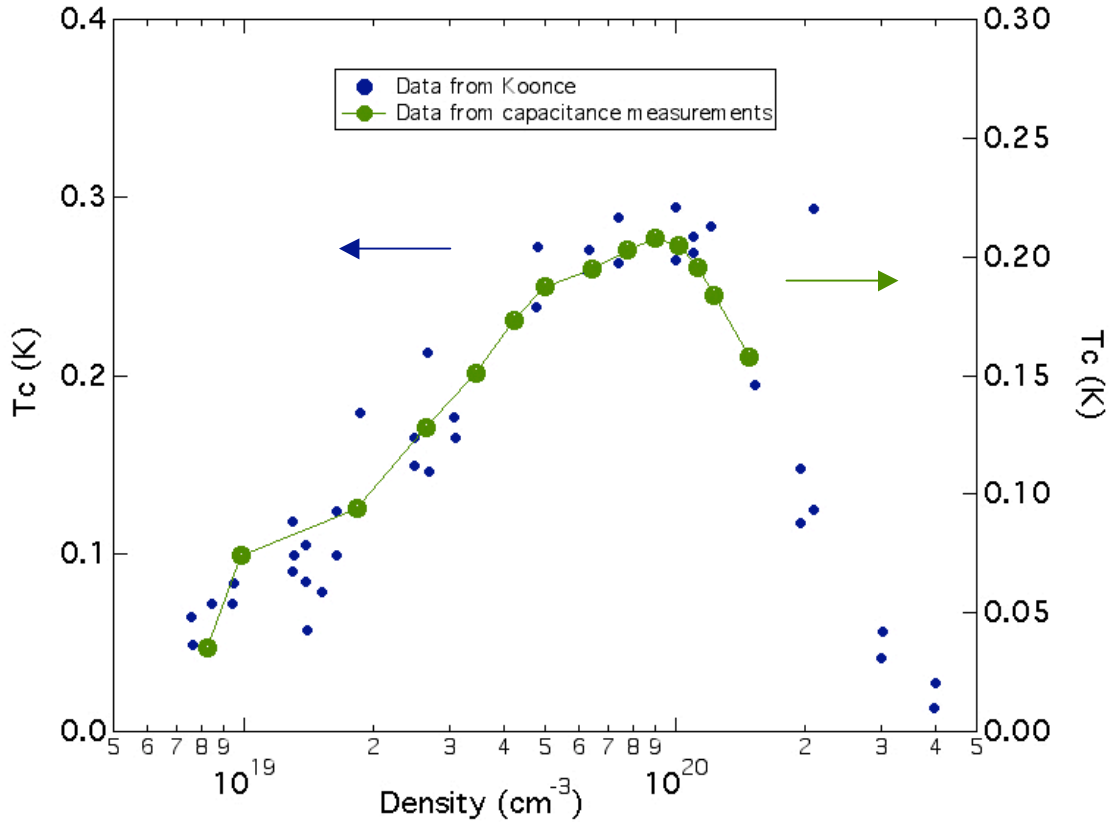
Capacitance measurements



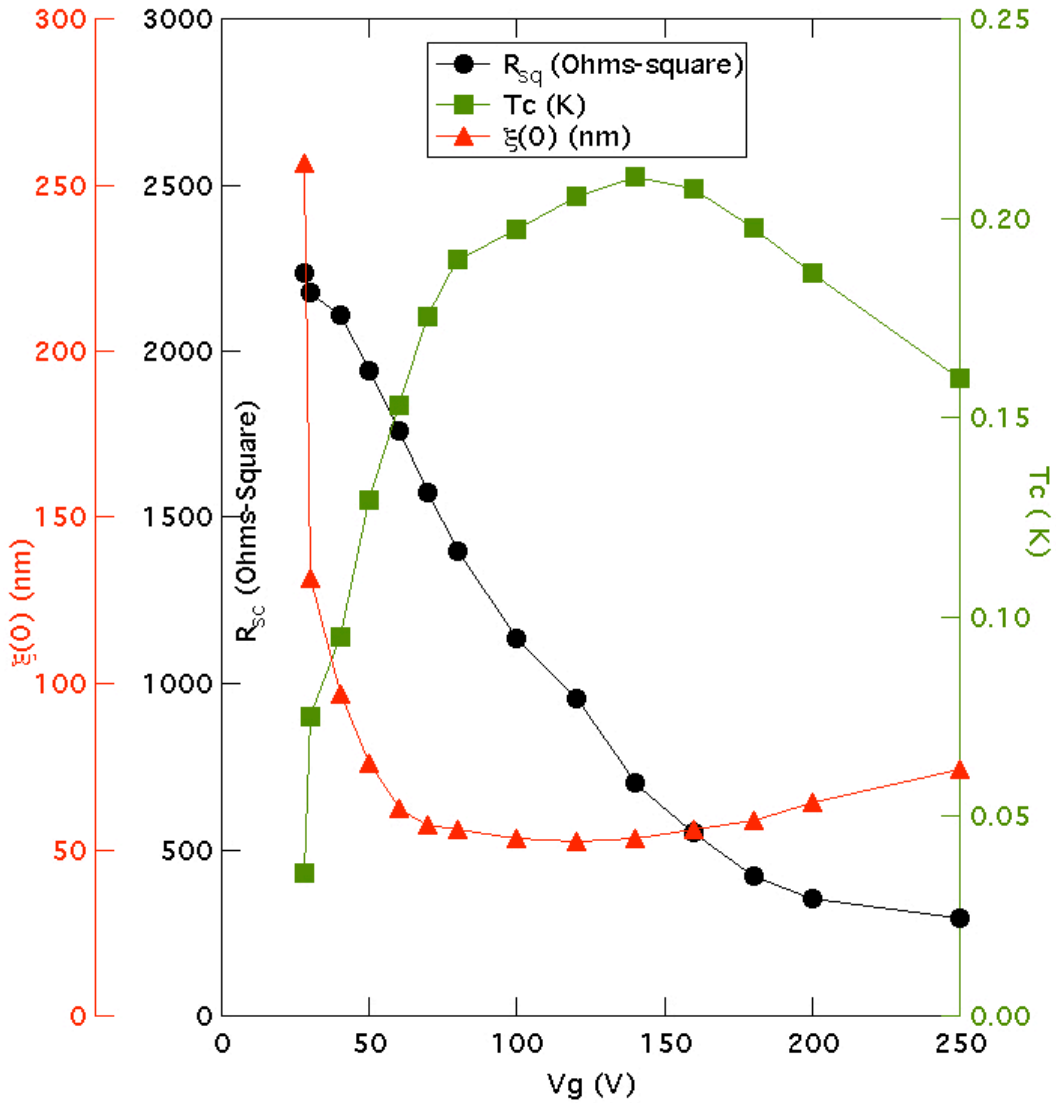


Sheet density absolute value for Tc max

d = 1.4 nm



Transport properties of the 2-DEG



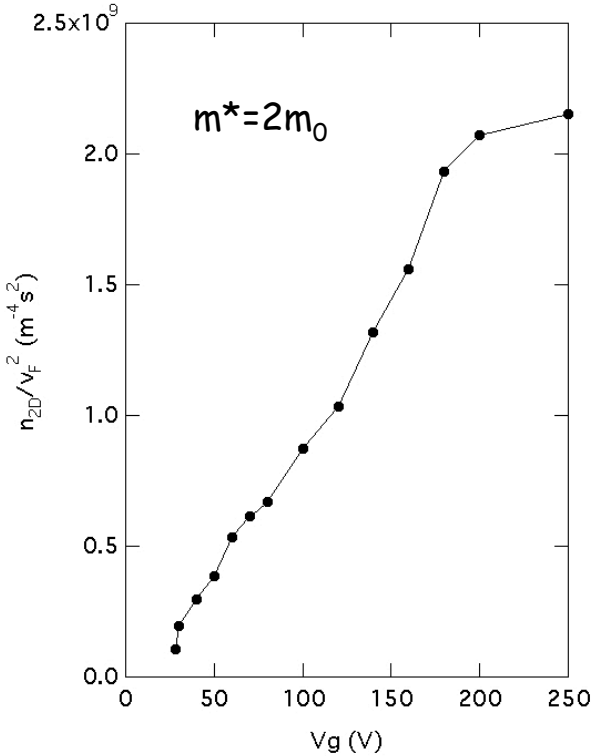
$$\mu_0 H_{c2} = \frac{\phi_0}{2\pi\xi(0)^2}$$

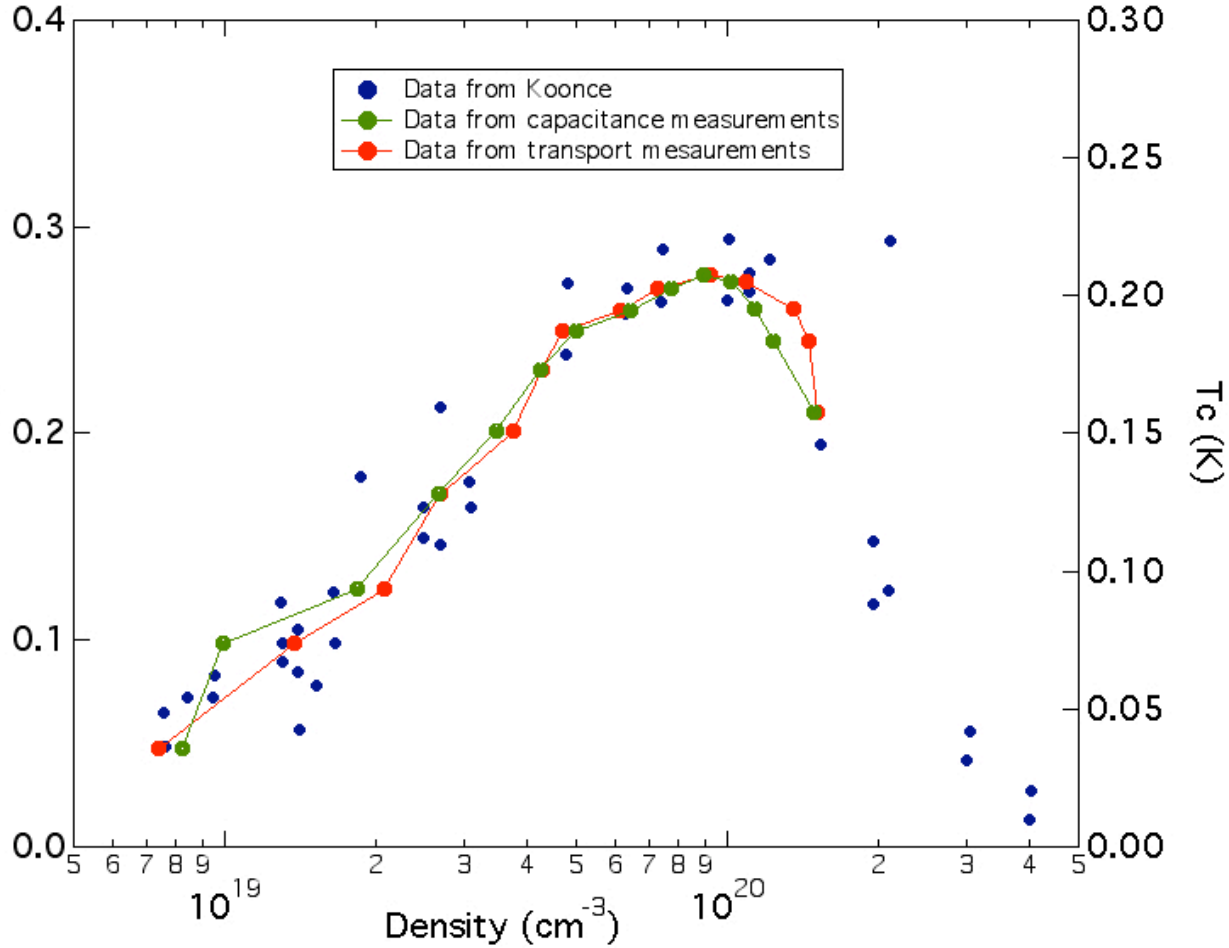
$$\xi(0) = \sqrt{\xi_0 l} \qquad \xi_0 = 0.133\frac{\hbar v_F}{k_B T_c}$$

$$R_{sq} = \frac{m^*}{n_{2D} e^2 \tau} \qquad l = v_F \tau$$

$$\frac{n_{2D}}{m^* v_F^{\,2}} = \frac{\hbar}{k_B T_c e^2 R_{sq} \xi(0)^2}$$

Transport properties of the 2-DEG

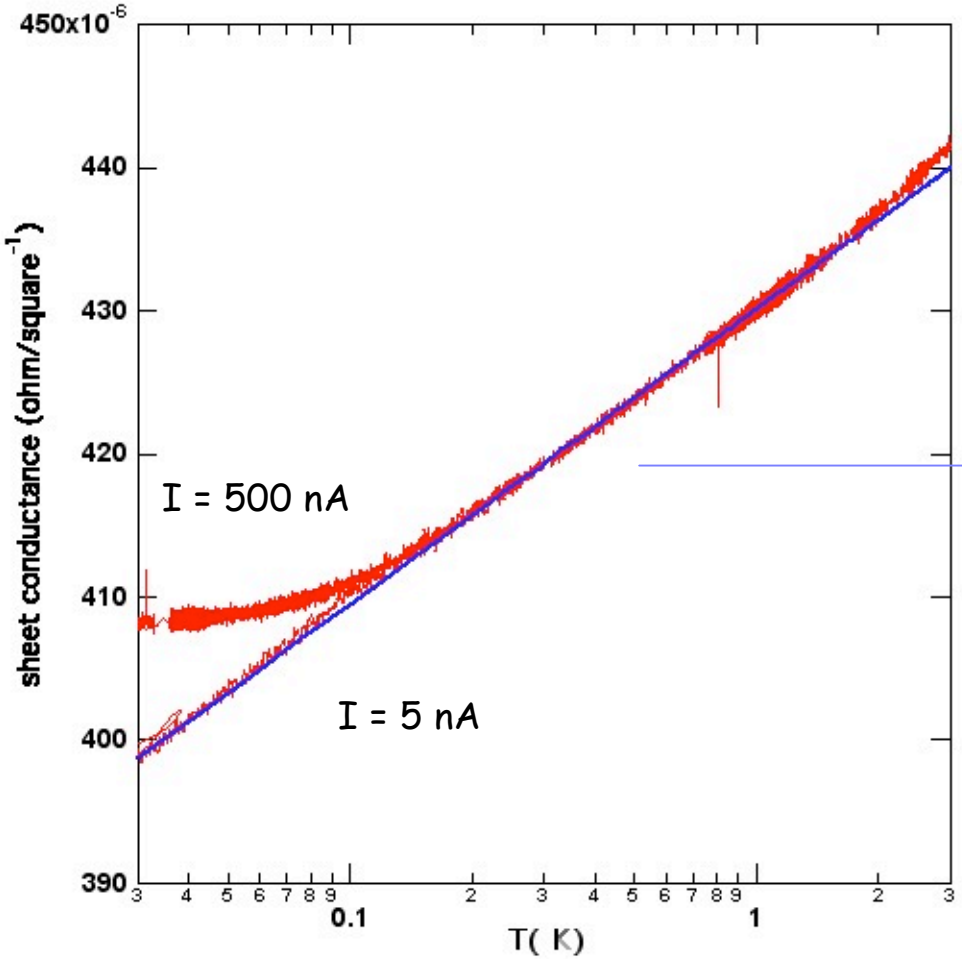




$v_F = 10^6$ cms^{-1} → d = 1.4 nm

Mainly doped $SrTiO_3$ properties at the interface

Weak localization regime



$$\sigma_{2D}(T) = \sigma_0 + \frac{p}{2}\frac{e^2}{\hbar\pi^2}\ln\left[\frac{T}{T_0}\right]$$

$$\tau_i \propto T^{-p}$$

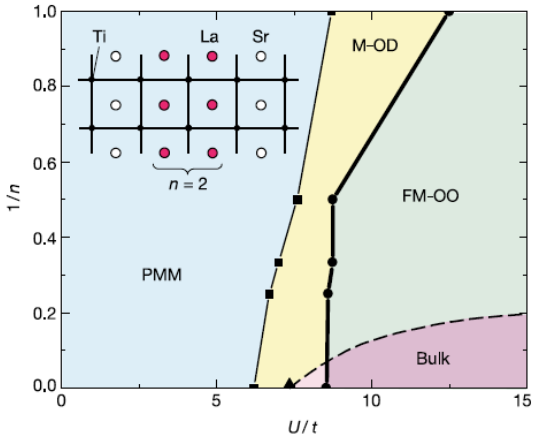
P = 1

Electron-electron scattering in 2D dirty limit

Abrahams et al PRB 1981

Conclusion

- ✓ Epitaxial growth of $LaTiO_3/SrTiO_3$
- ✓ Evidence of of 2DEG at the Mott Insulator/Band Insulator interface
- ✓ Discovery of superconductivity at 200-300 mK
- ✓ Mainly doped $SrTiO_3$ properties at the interface
- ✓ Electric field induced superconductor-insulator transition
- ✓ To come … thinner $LaTiO_3$ layers with electronic orders



Okamoto et al Nature 2004

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