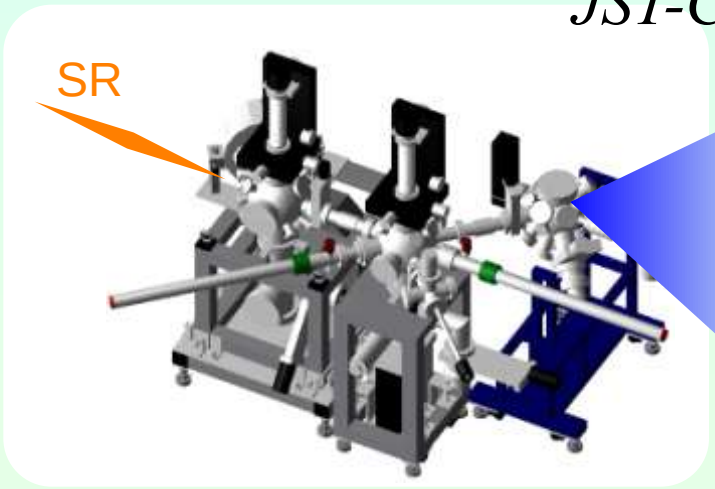
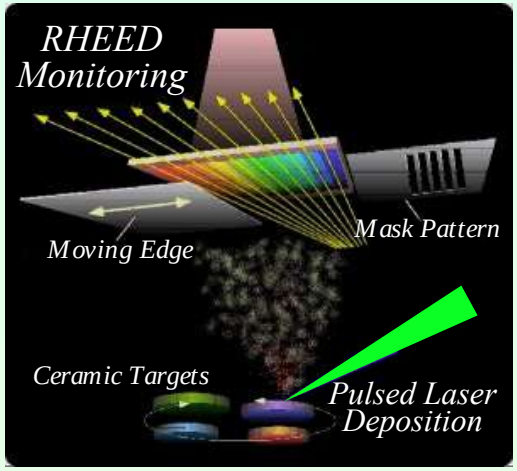
PFユーザー研究会　―PFの挿入光源における新しい研究の探究―
平成21年1月13日（13-14日）@KEK-PF国際交流センター

放射光電子分光でみる酸化物ヘテロ界面電子状態

組頭　広志
東京大学大学院工学系研究科
JST-CREST

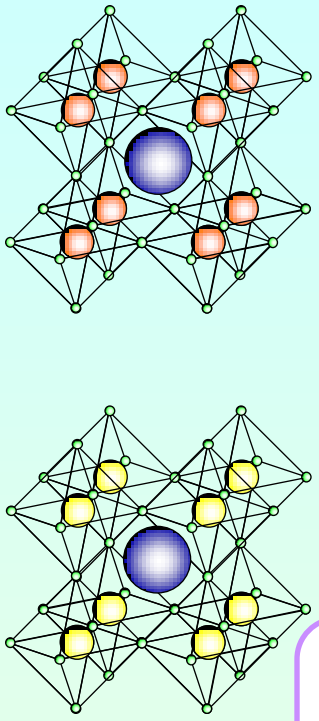


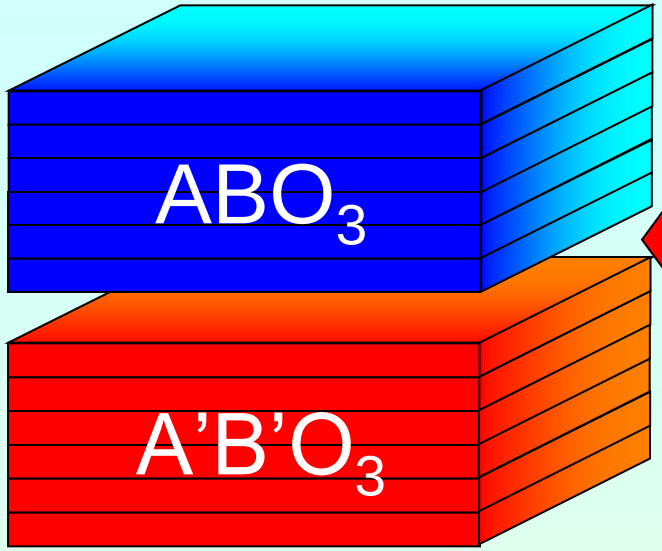


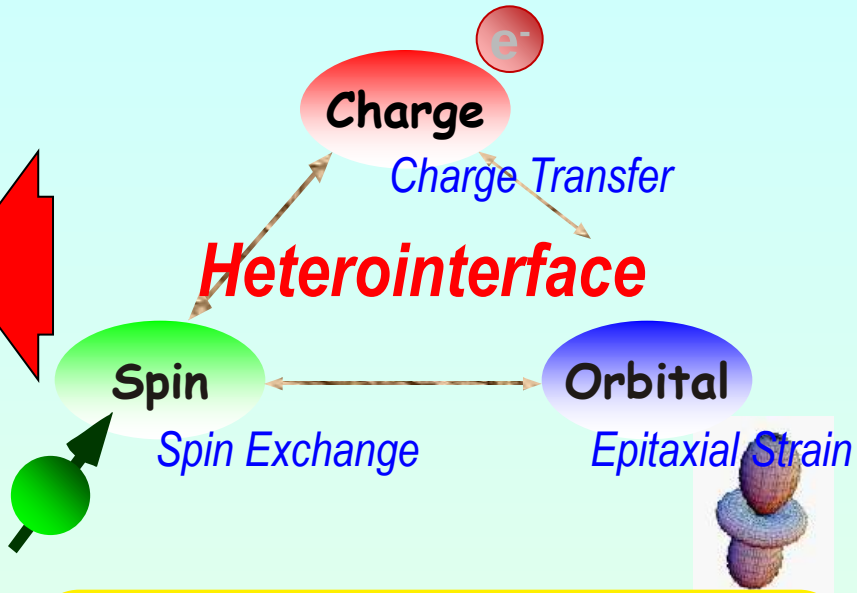
INTRODUCTION

Heterojunctions based on Perovskite Oxides

Controlling physical properties using interface effects

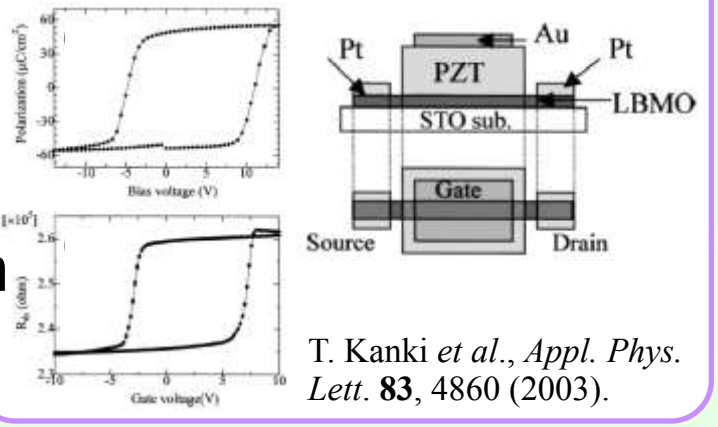






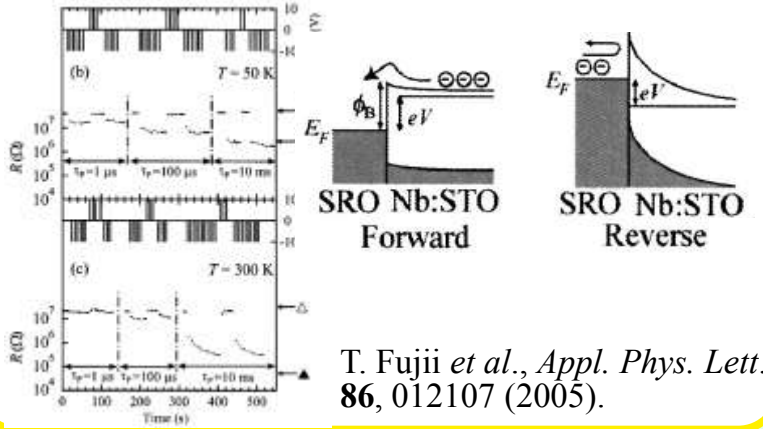
High Tc
CMR
MI transition

Ferroelectric FET



T. Kanki *et al.*, *Appl. Phys. Lett.* **83**, 4860 (2003).

Resistance RAM



T. Fujii *et al.*, *Appl. Phys. Lett.* **86**, 012107 (2005).

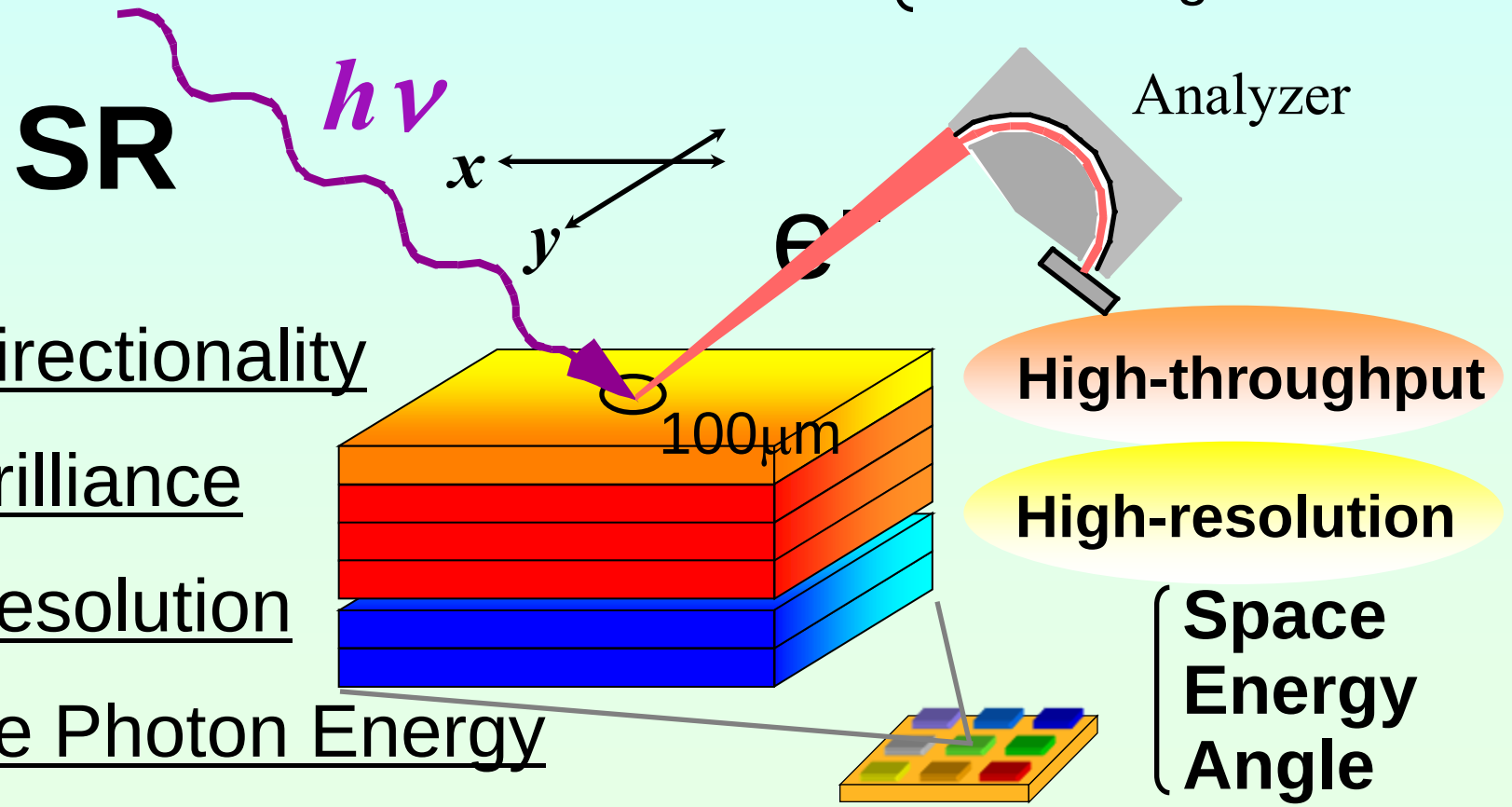
Advantage of SR-PES

☆Non-destructive

☆Surface (Interface) Sensitive （5∽30 Å）

☆Direct Determination of Electronic States
- Chemical Shift
- DOS
- Band Diagram

Hard-XrayPES@SPring-8 (∽1000 A)



High Directionality

High Brilliance

High Resolution

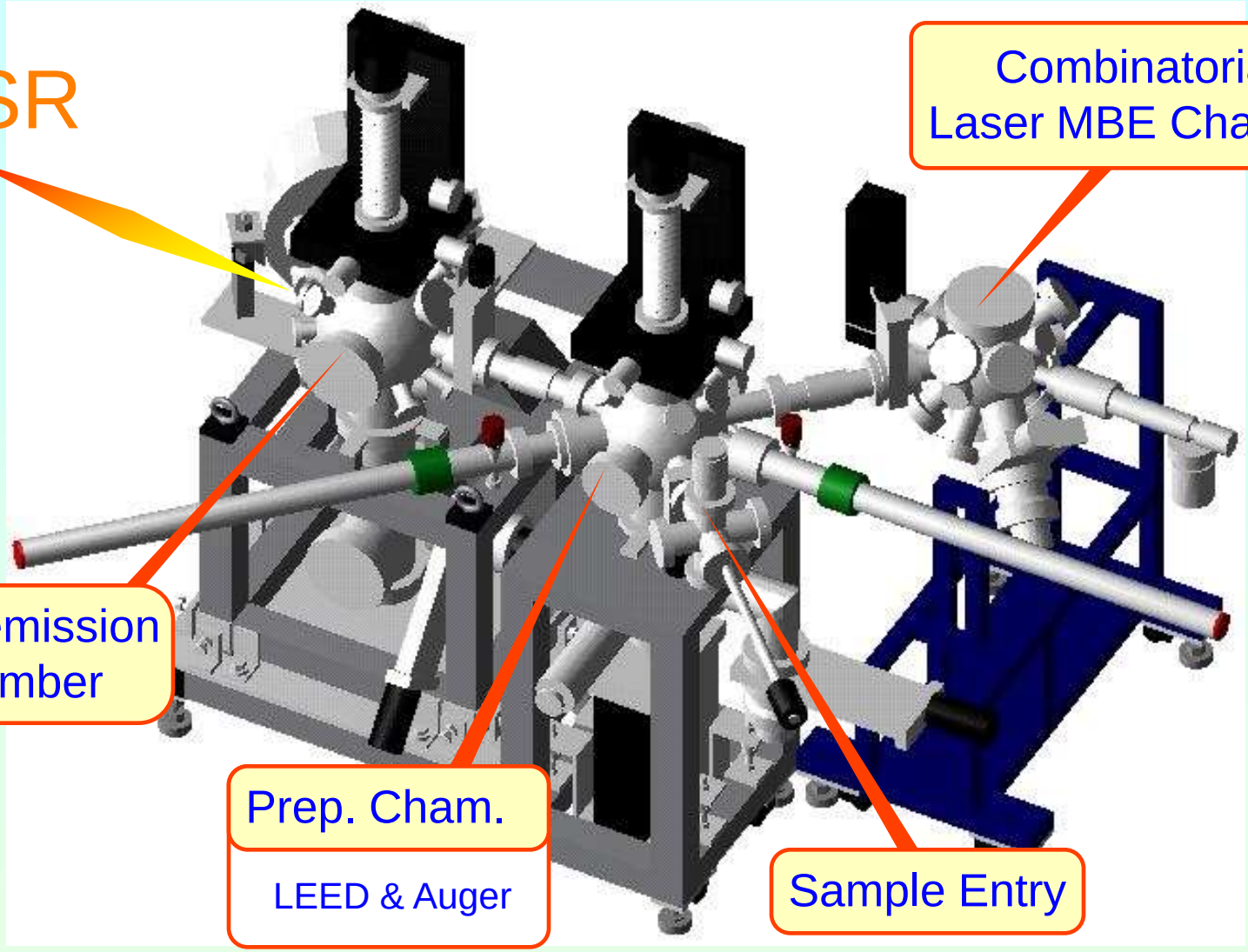
Tunable Photon Energy

High-throughput

High-resolution

Space
Energy
Angle

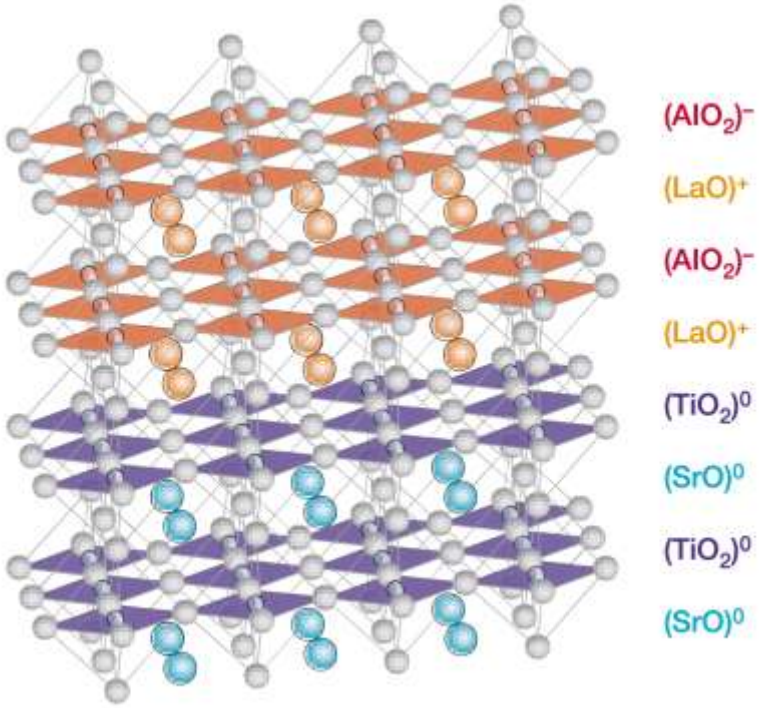
In-situ PES + Laser MBE system



K. Horiba, HK *et al*., Rev. Sci. Instrum. **74**, 3406 (2003).

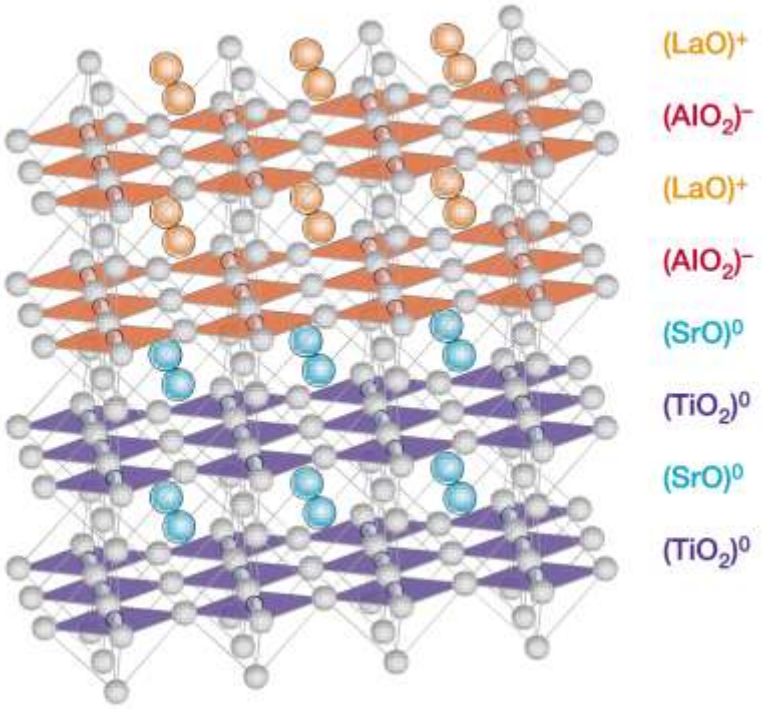
Interfacial Electronic Structure of $LaAlO_3$/ $SrTiO_3$ Heterojunctions

$LaAlO_3$ /TiO_2-$SrTiO_3$



n-type (Metallic)

$LaAlO_3$ /SrO-$SrTiO_3$



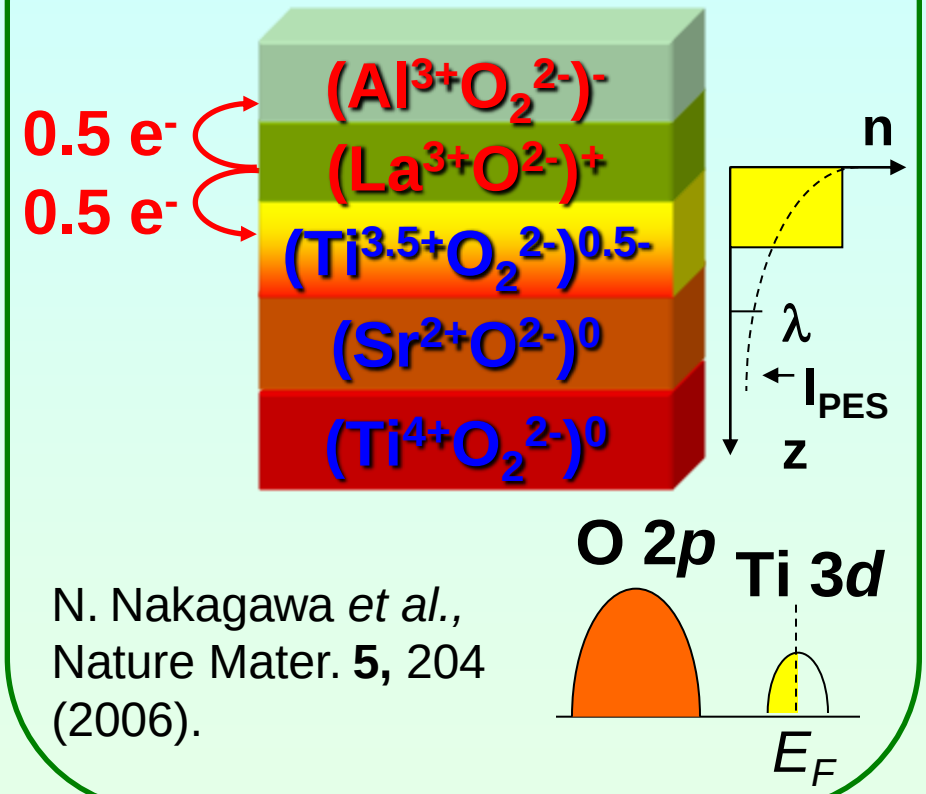
p-type (Insulating)

A. Ohtomo and H. Y. Hwang, Nature **427**, 423 (‘04).

Origin of the Metallic Interface

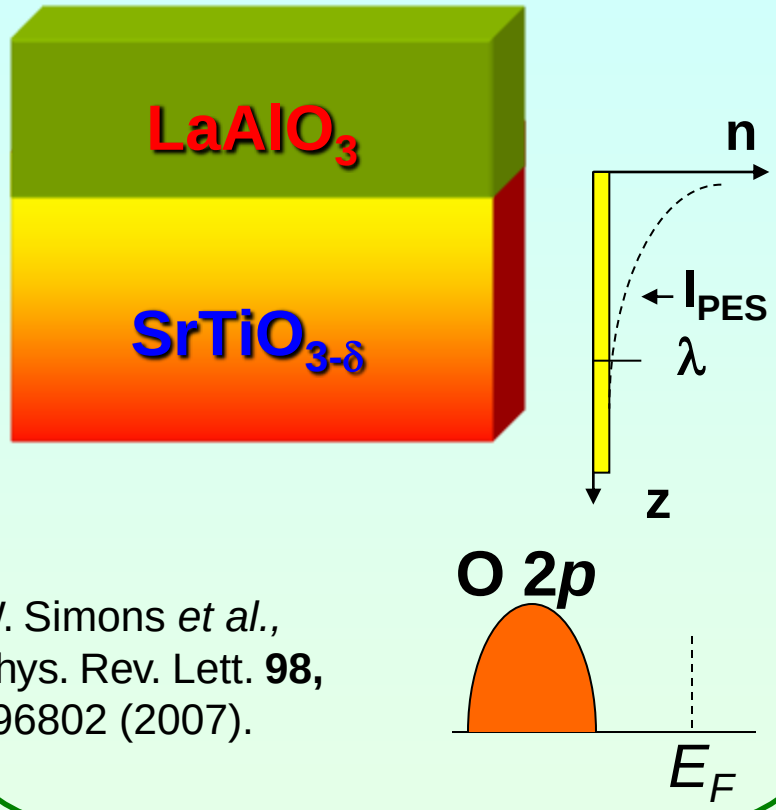
1. Charge Transfer

$2Ti^{4+}(d^0) + e^- \rightarrow Ti^{3+}(d^1) + Ti^{4+}$



N. Nakagawa *et al.*, Nature Mater. **5,** 204 (2006).

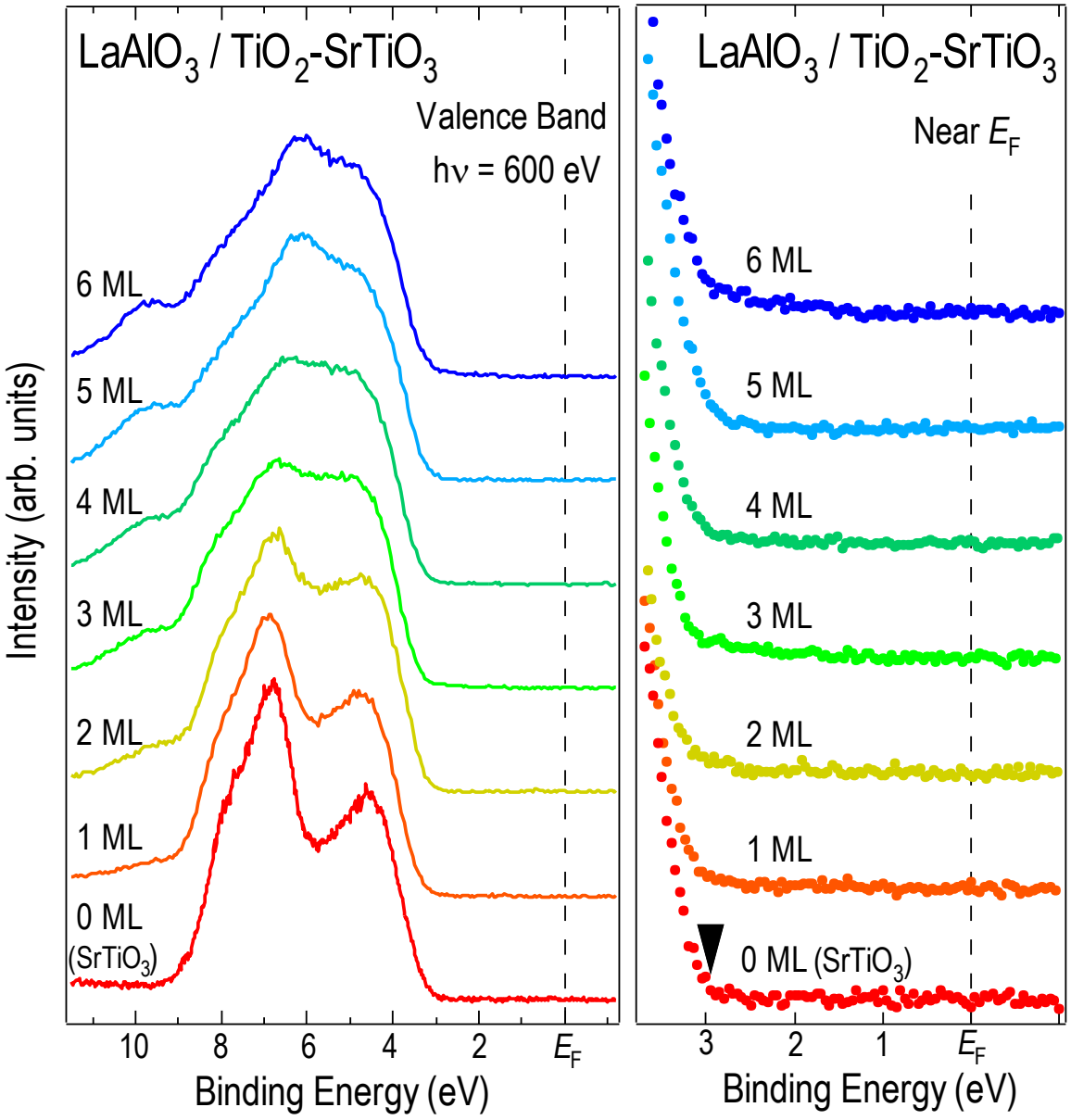
2. Oxygen Vacancies



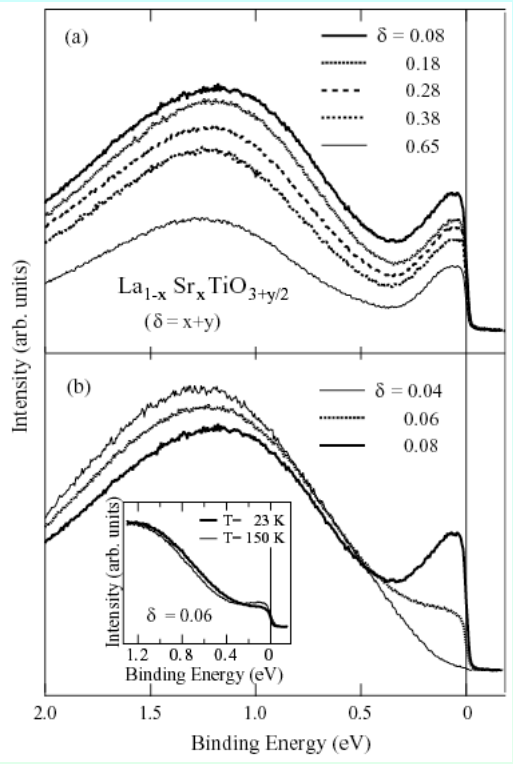
W. Simons *et al.*, Phys. Rev. Lett. **98,** 196802 (2007).

DOS at E_F is different between the two scenarios.

Valence Band Spectra of n-type Interfaces



PES spectra of LSTO

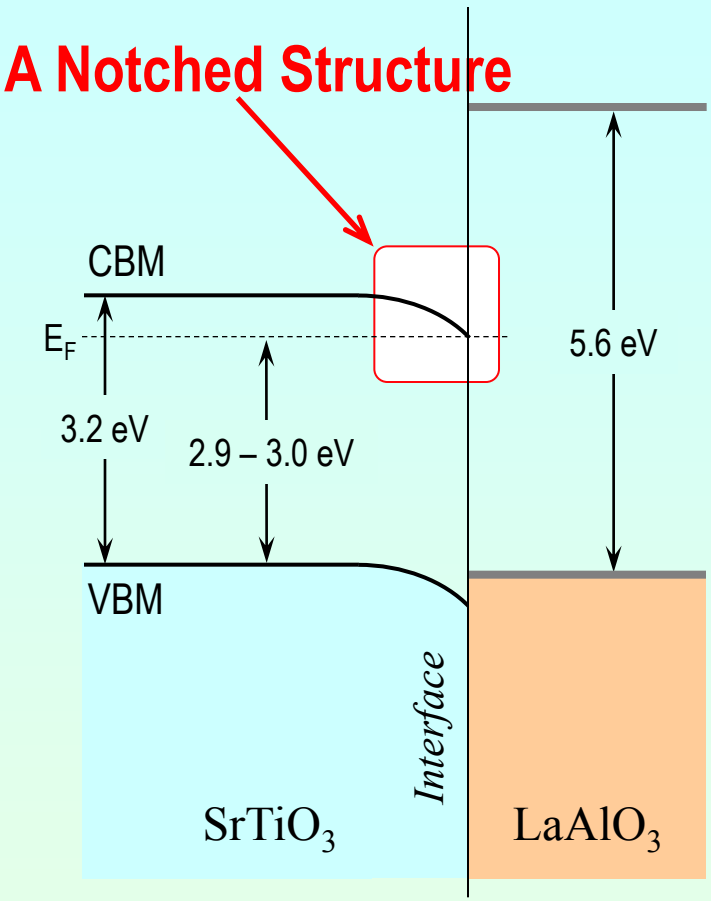


T. Yoshida *et al.*, Europhys. Lett. **59**, 258 ('02)

No detectable Ti 3*d* DOS at E_F

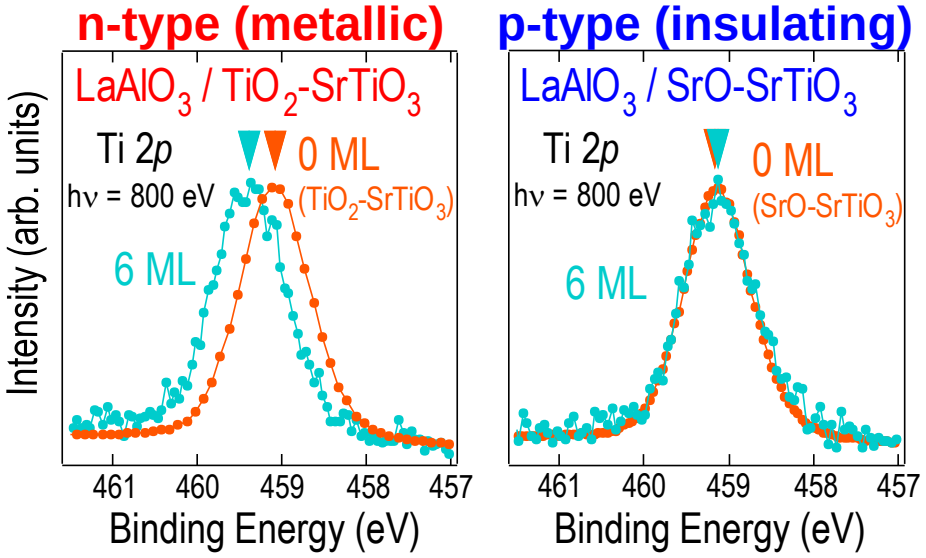
K. Yoshimatsu, HK *et al.*, *Phys. Rev. Lett.* **101**, 026802 (08).

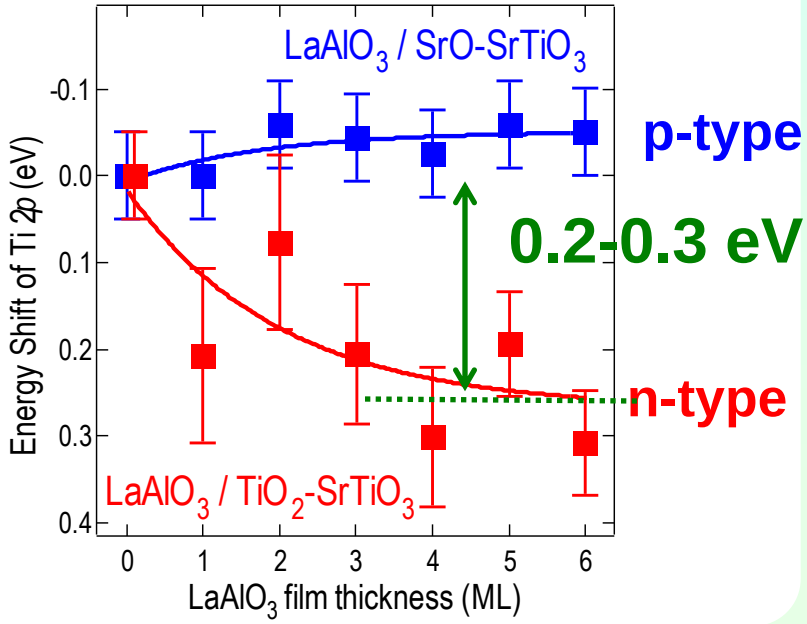
Band Diagram of LAO/STO Interface



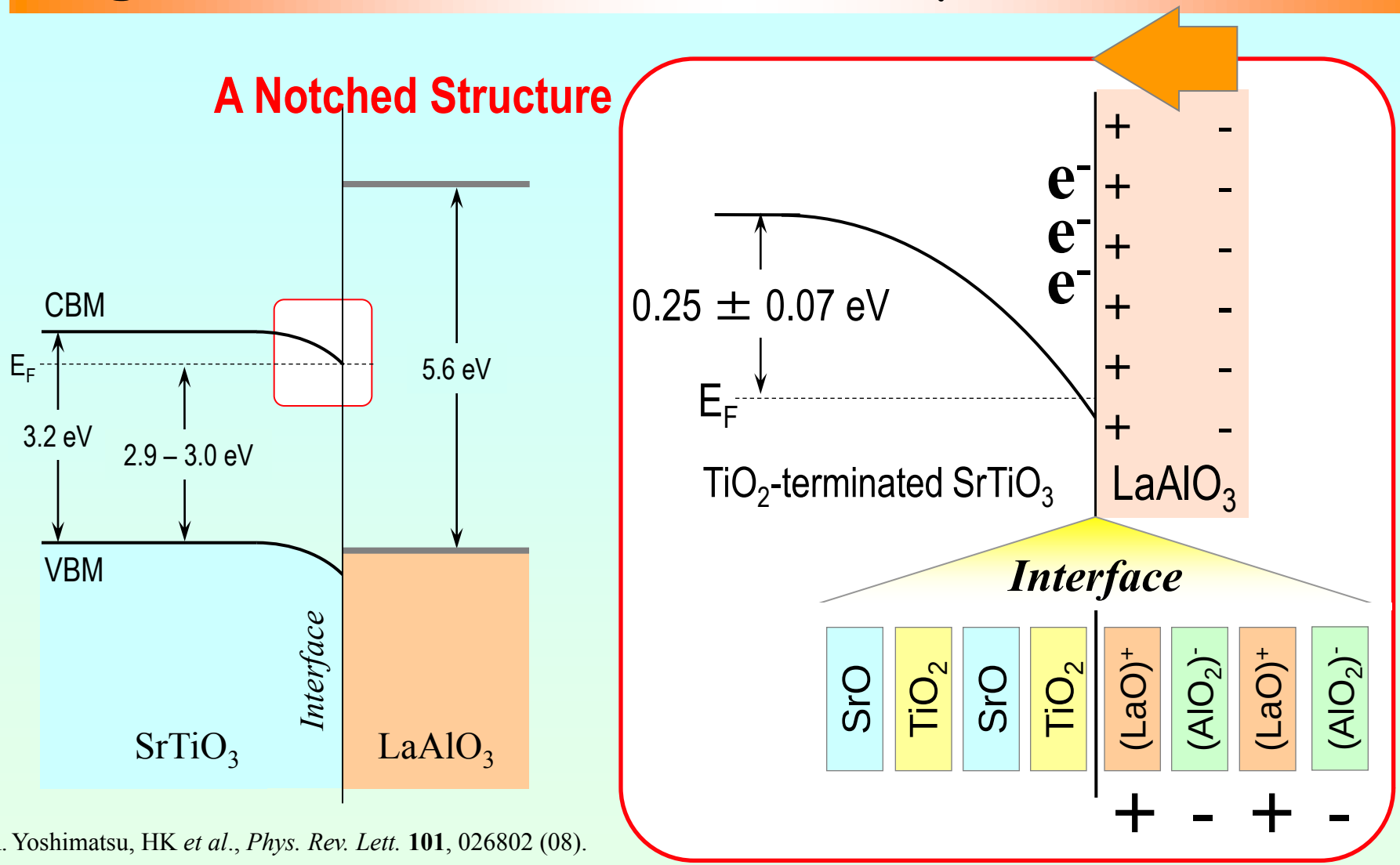
Band bending of 0.2-0.3 eV to higher binding energy from STO to the metallic interface.

Ti 2*p* core level spectra





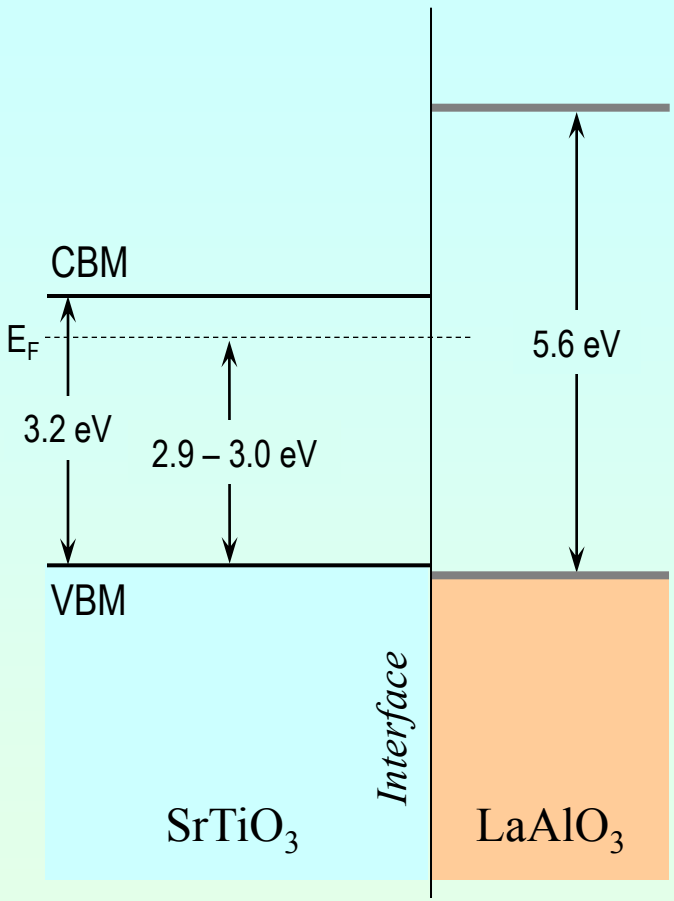
Origin of Metallic Conductivity in LAO/STO

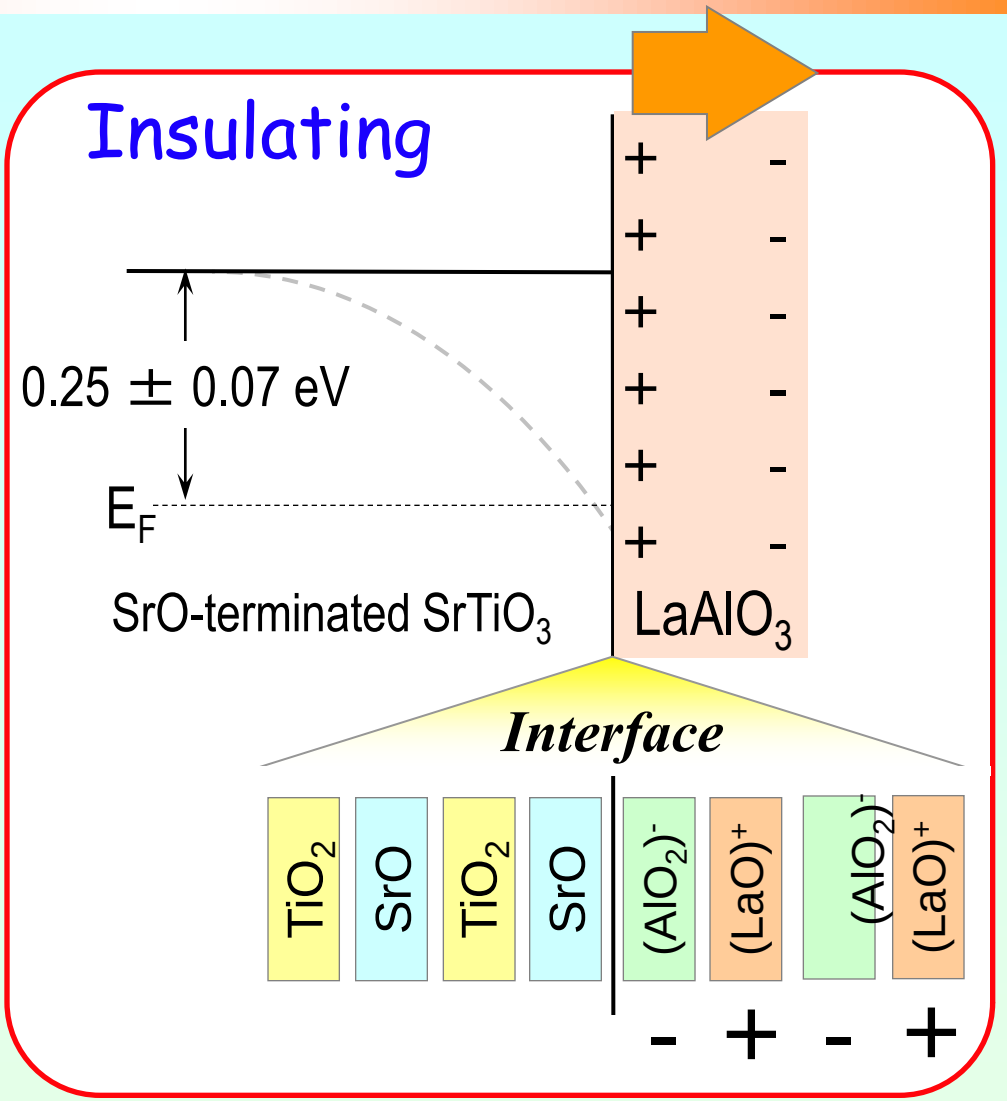


K. Yoshimatsu, HK *et al.*, *Phys. Rev. Lett.* **101**, 026802 (08).

The metallic conductivity originate from the accumulation of carriers on the notched structure formed at the interface.

Origin of M-I Transition by Inserting SrO





K. Yoshimatsu, HK *et al*., *Phys. Rev. Lett.* **101**, 026802 (08).

The notched structure disappears by inserting SrO atomic layer between LAO and STO.

まとめ

LaserMBE装置と光電子分光装置を連結したin-situ光電子分光装置を立ち上げ、酸化物ヘテロ構造について調べた。

1. LSMO/LSFO, LSMO/STO
   界面を通した遷移金属イオンの電荷移動は3d準位の位置と占有数で決まる。
2. LAO/STO
   界面を通した電荷移動は起こっておらず、金属伝導の起源は界面に形成されたノッチ構造への電子の蓄積である。

放射光の「元素選択性」を用いた放射光電子分光は酸化物ヘテロ構造の研究に非常に有効

We desire

UNDULATOR

High Photon-Flux

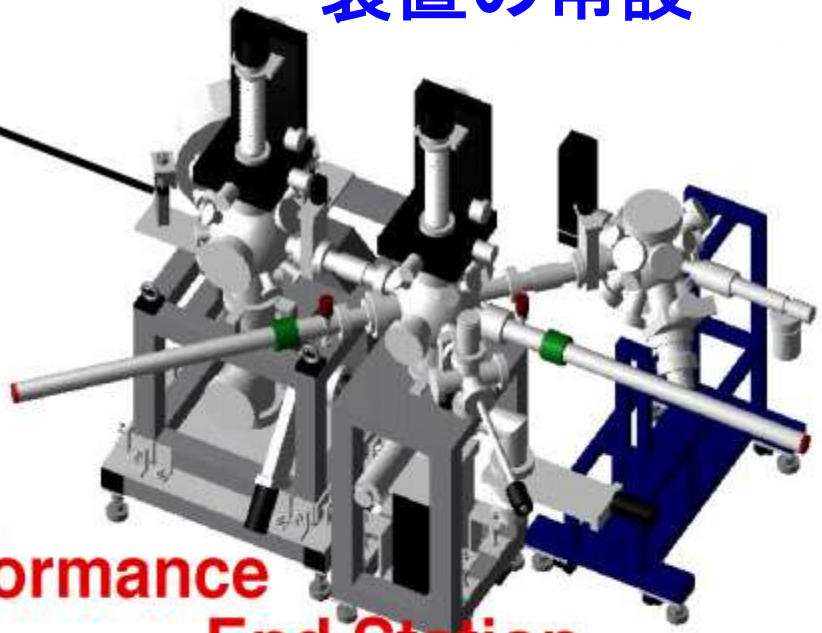
&

High Energy Resolution

ビームラインの
安定性

長期ビームタイム

装置の常設



使いやすい装置
（ユーザーインターフェース）

High-Performance
End Station

解析プログラムの整備

for in-situ PES