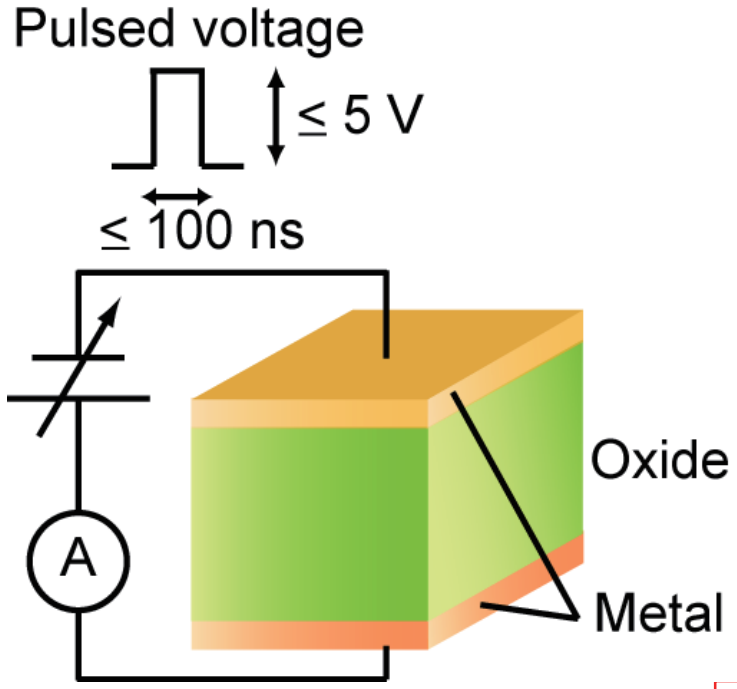
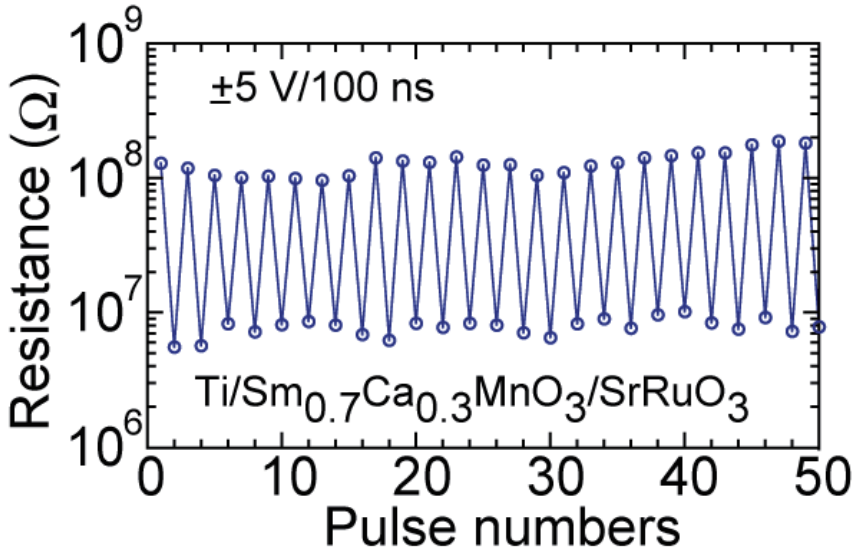
Resistive switching effect of transition metal oxides



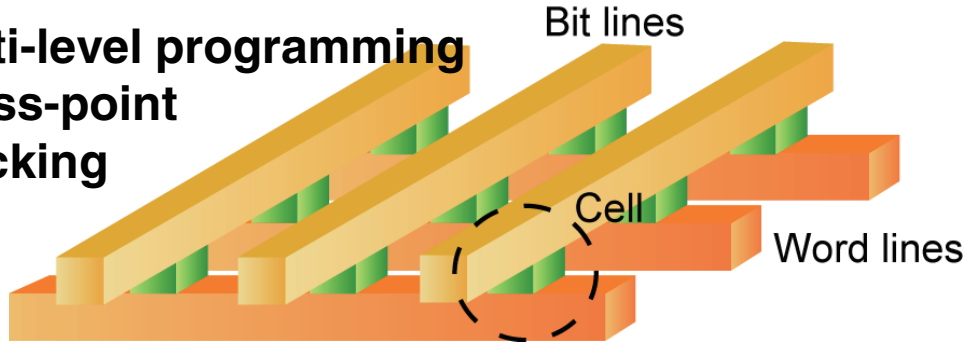


Capacitor-like structure

$(Pr,Ca)MnO_3$,
Cr:$SrZrO_3$ or $SrTiO_3$,
$LaCoO_3$, NiO, TiO_2
etc.

Resistance Random Access Memory (ReRAM)

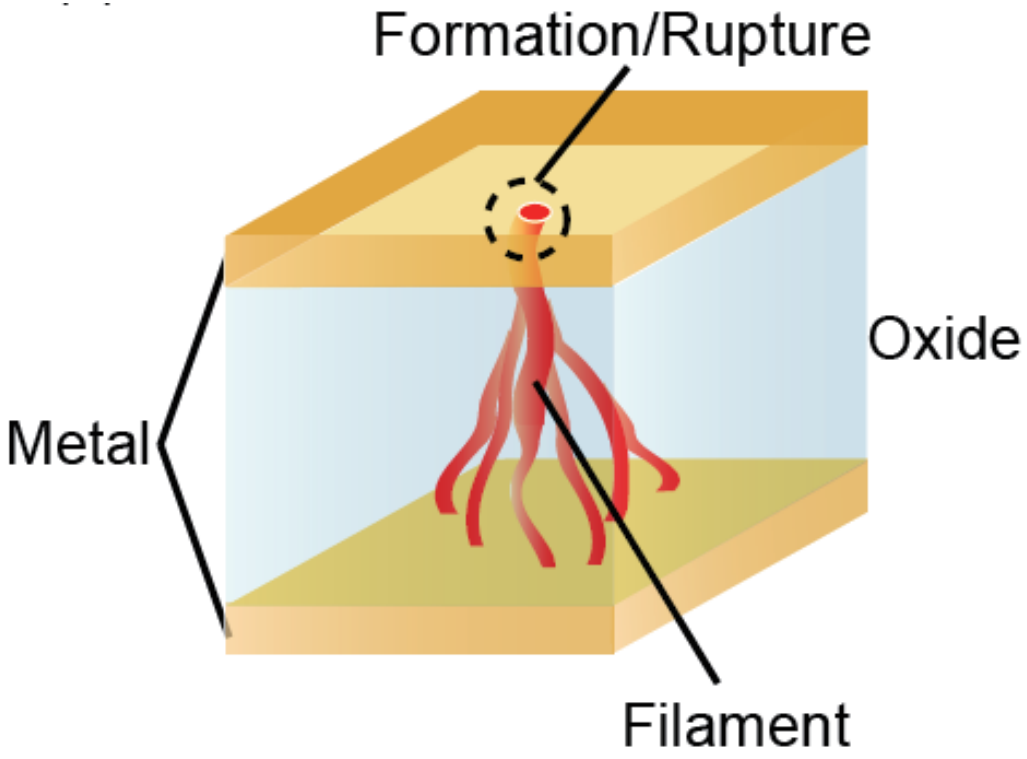
- **Multi-level programming**
- **Cross-point**
- **Stacking**



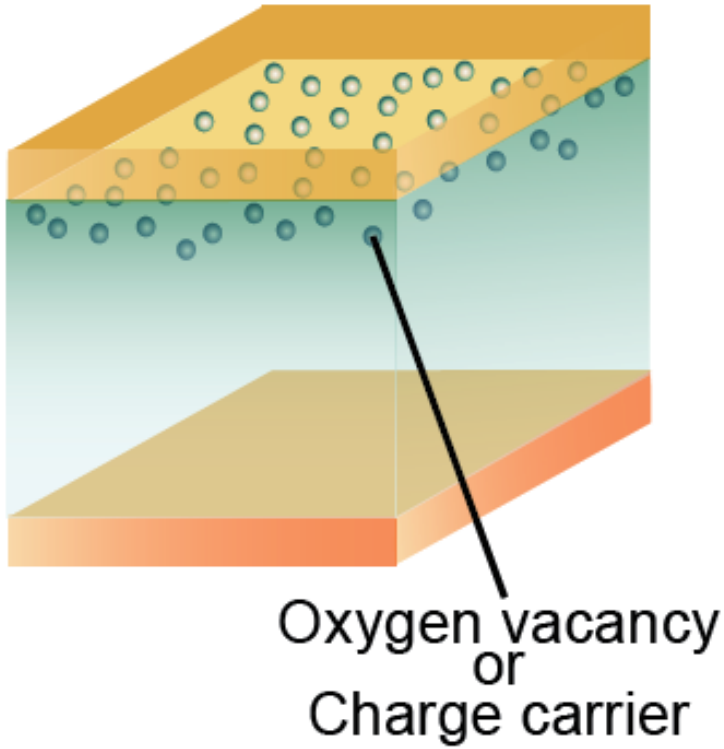
Sawa, Materials Today **11**, 6, 28 (2008).

Classification of resistive switching mechanisms

Filament type

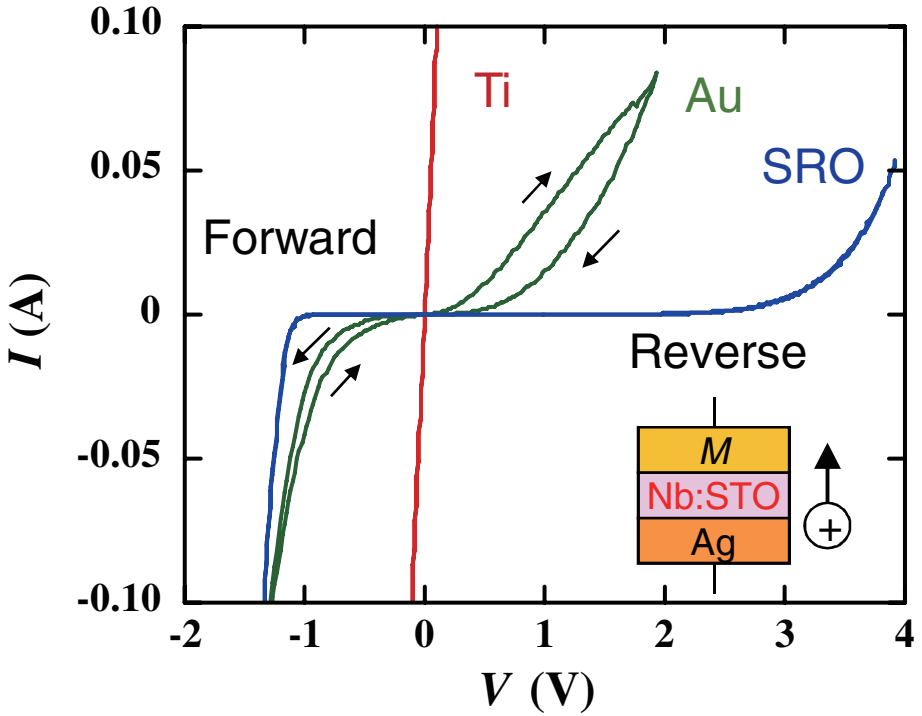


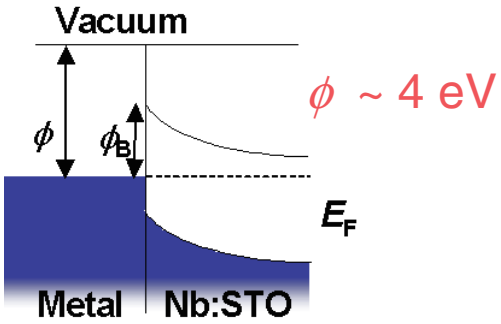
Interface type



Interfacial resistive switching

Metal/Nb:STO (x = 0.01)



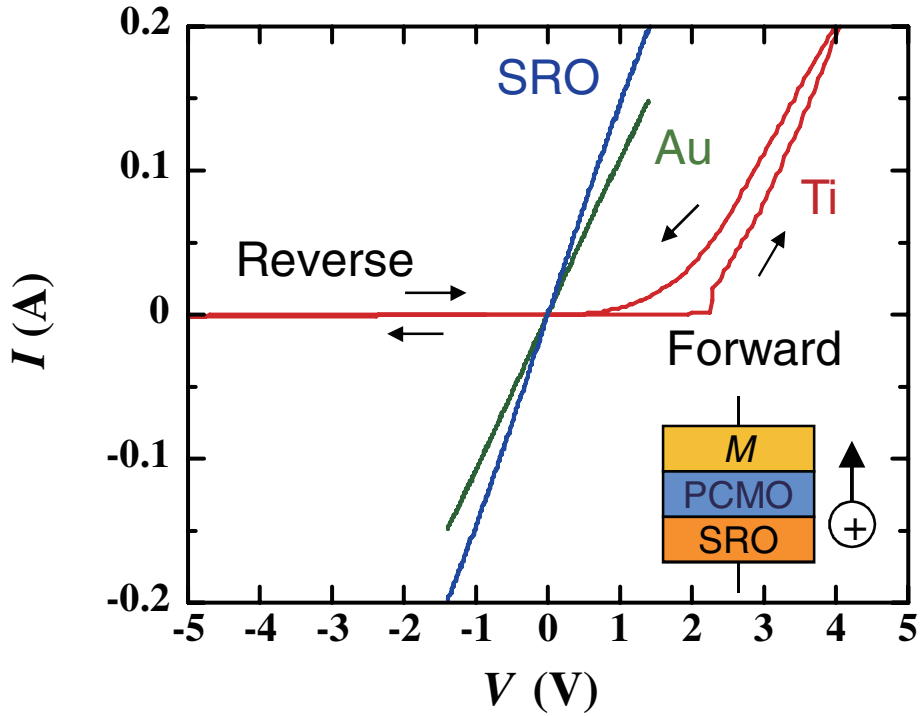


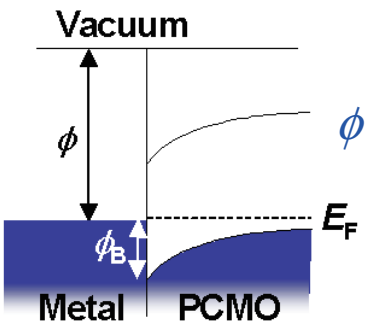
ϕ ~ 4 eV

	ϕ (eV)
Ti	~4.3
Au	~5.1
SRO	5.0 - 5.3

Deep ϕ metal (Au, SRO) + *n*-type

Metal/PCMO

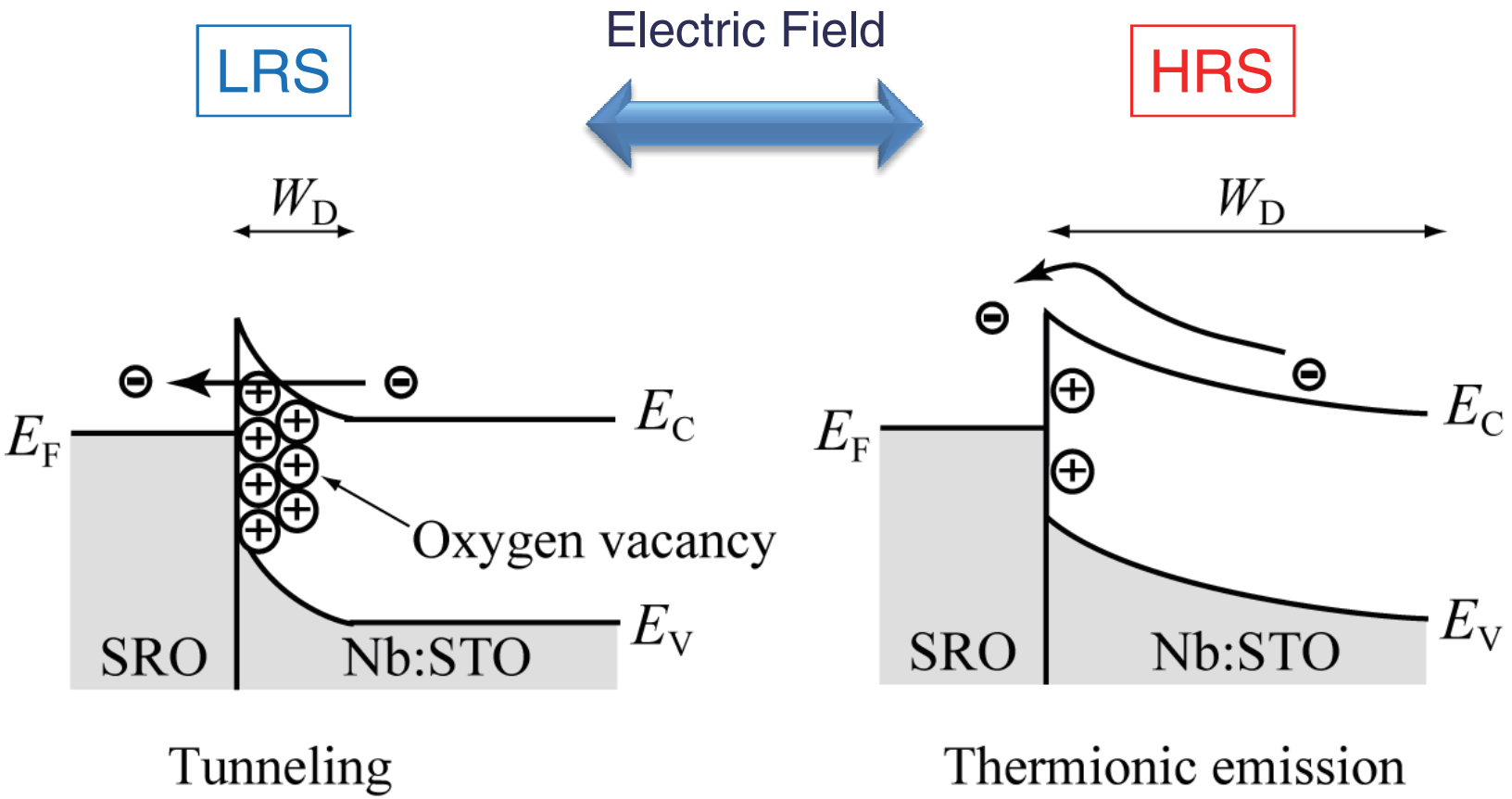




ϕ ~ 4.5 eV

Shallow ϕ metal (Ti) + *p*-type

A possible model of resistive switching



Potential profile of depletion layer is modified by space charge

電気化学的効果による酸素イオンの移動

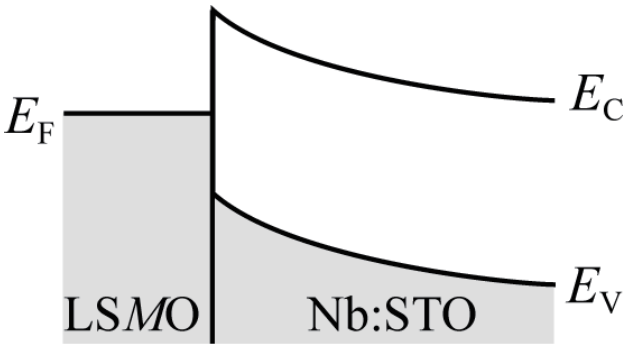
Interfacial band structure probed by transport properties

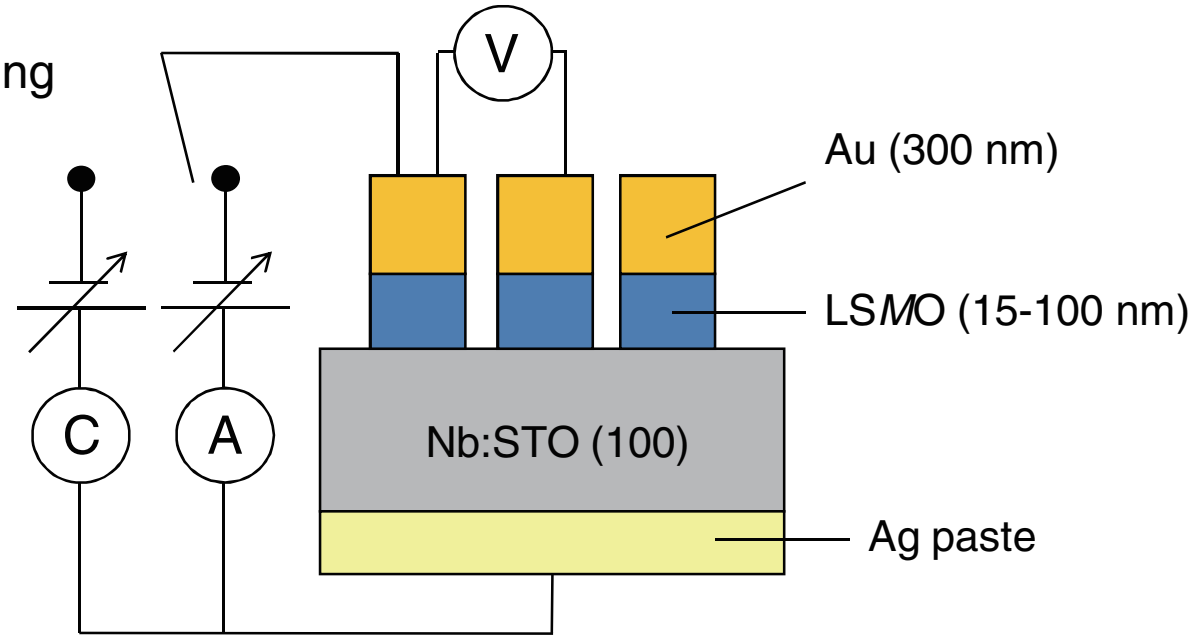
$La_{1-x}Sr_xMO_3/SrTi_{0.99}Nb_{0.01}O_3$ (*M*=Mn, Fe, Co, and Ni) interfaces
(LS*M*O/Nb:STO)

- Band filling (*x*) dependence of interfacial band structure
- Material dependence of interfacial band structure

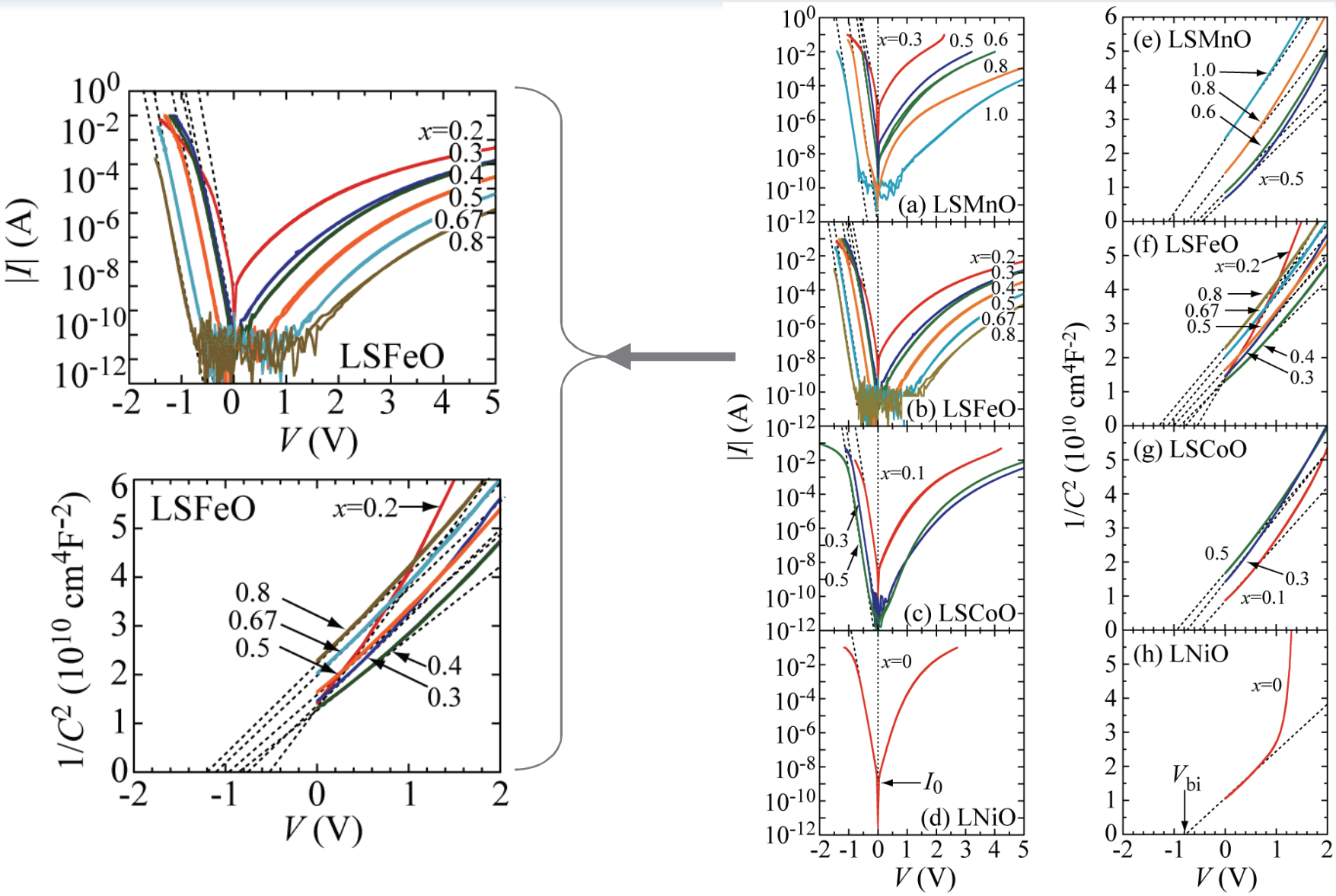
LS*M*O/Nb:STO junctions

- Pulsed laser deposition (PLD)
- Photolithography & Ar ion milling
- 100 x 100 μm^2
- *I-V* and *C-V* measurements



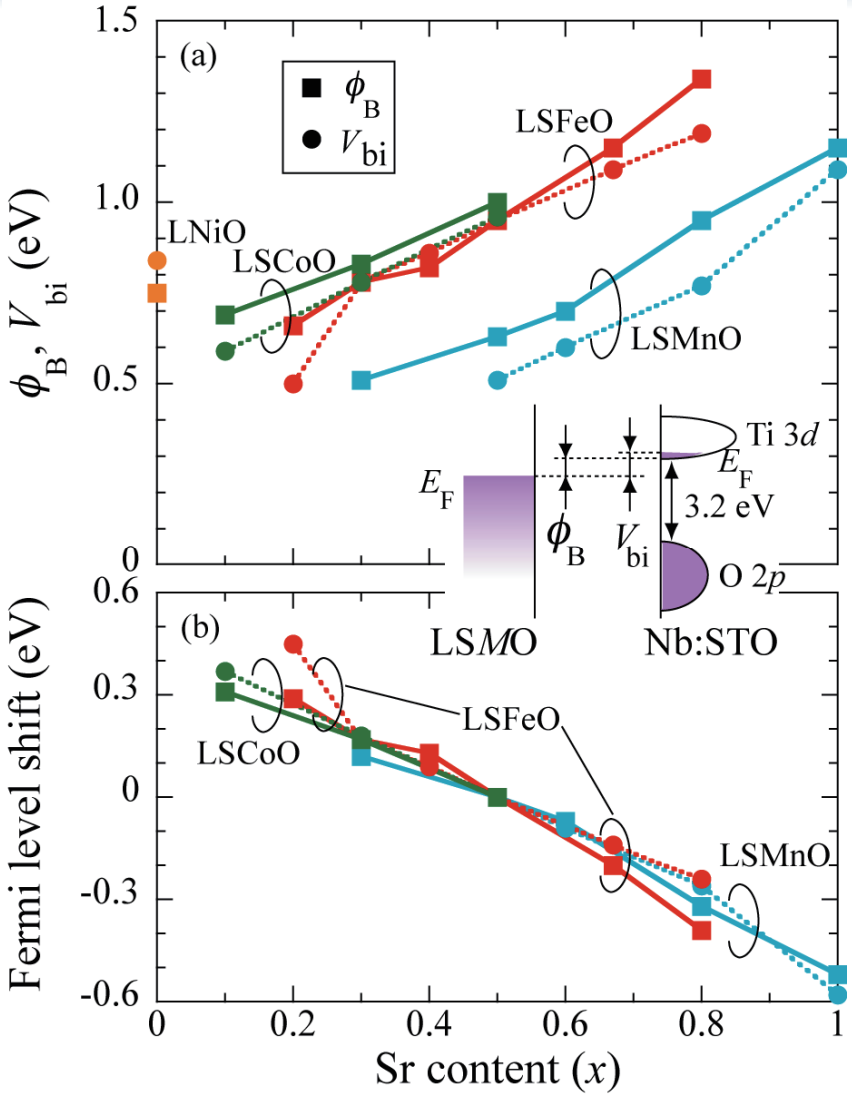


I-V and *C-V* characteristics



Yamamoto *et al.*, APL**90**, 112104 (2007); Sawa *et al.*, APL**90**, 252102 (2007)

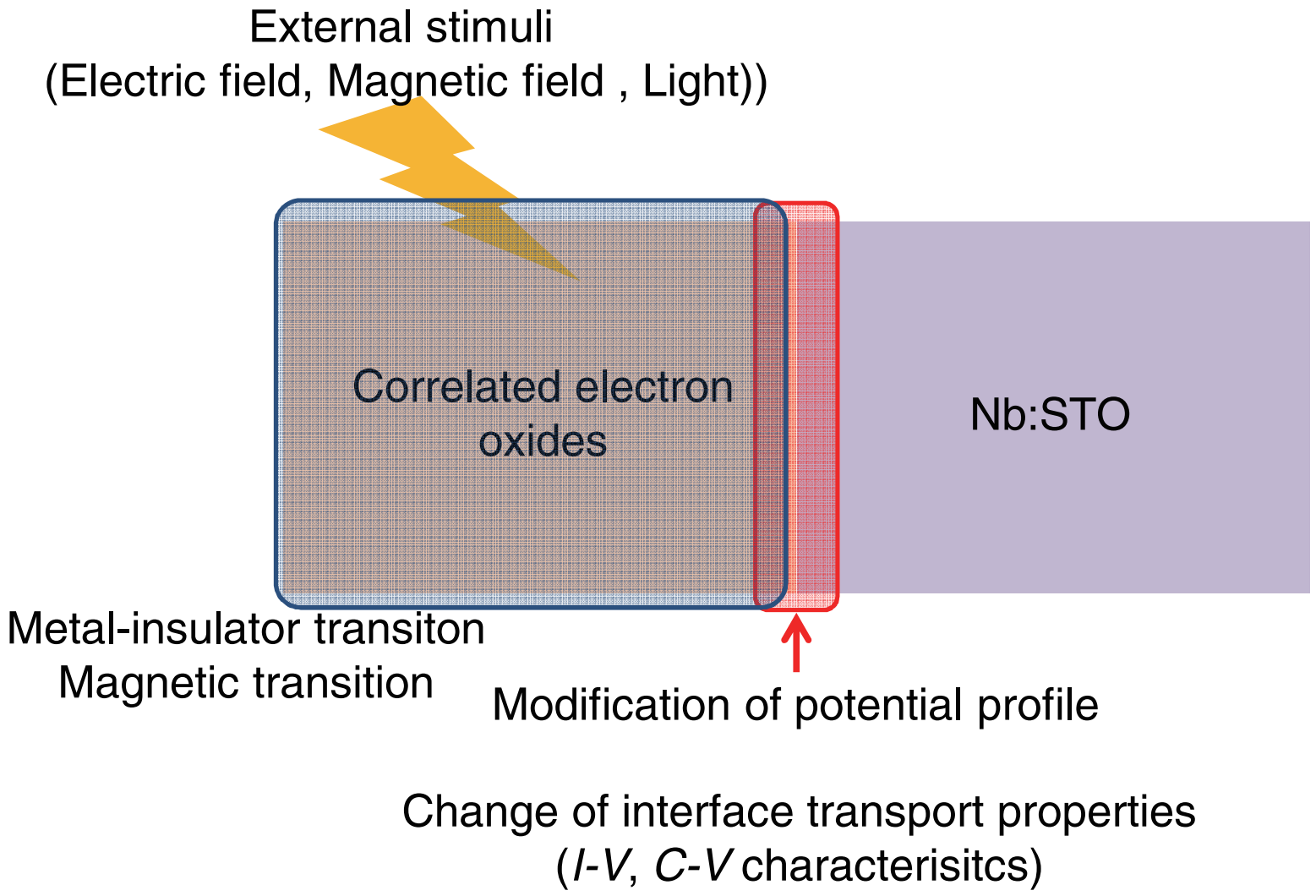
Band filling dependence of Fermi-level position



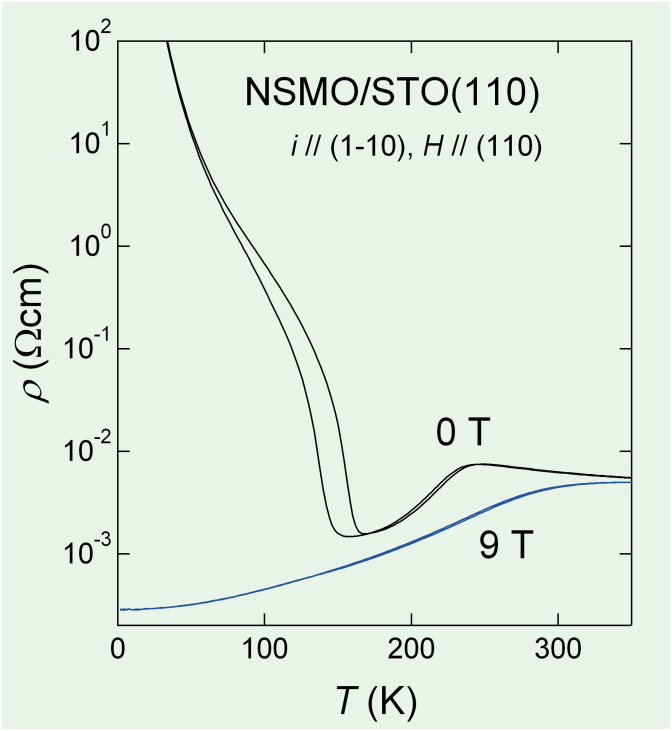
Fermi-level position shifts downward with carrier doping, as –*x* (eV)

Sawa *et al.*, APL**90**, 252102 (2007)

Modification of interface properties by external stimuli



Magnetic control of interface properties



$Nd_{0.5}Sr_{0.5}MnO_3$ epitaxial thin films

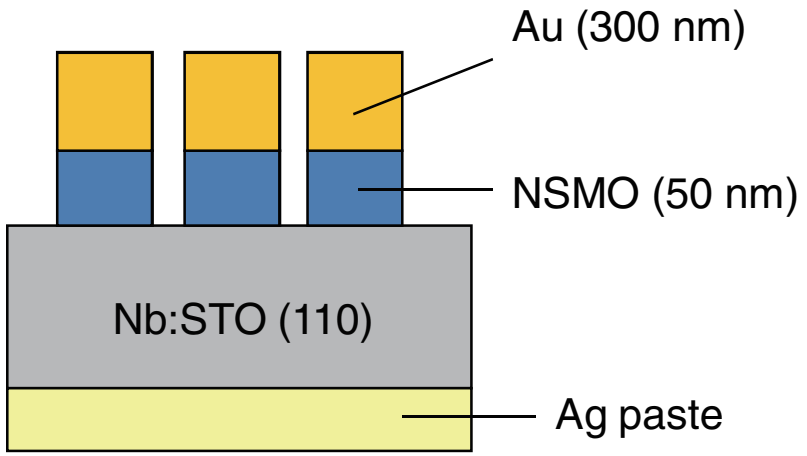
Metal-insulator transition
induced by magnetic field *H*

↓

Change of interface transport properties?

NSMO/Nb:STO junctions

- Nb: 0.02 mol%
- Pulsed laser deposition (PLD)
- P_{O2} = 3 mTorr, T_{sub} = 900°C
- Conventional photolithography & Ar ion milling



I-V characteristics

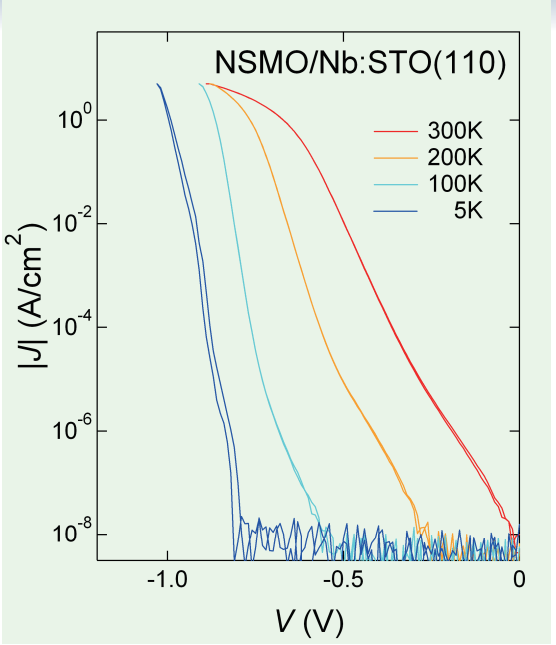
T-dependence

- The forward bias *J*–*V* characteristics

  the conventional theory for

  a *p*-*n* (or Schottky) diode

  → V_{BI} ~ 0.8 eV

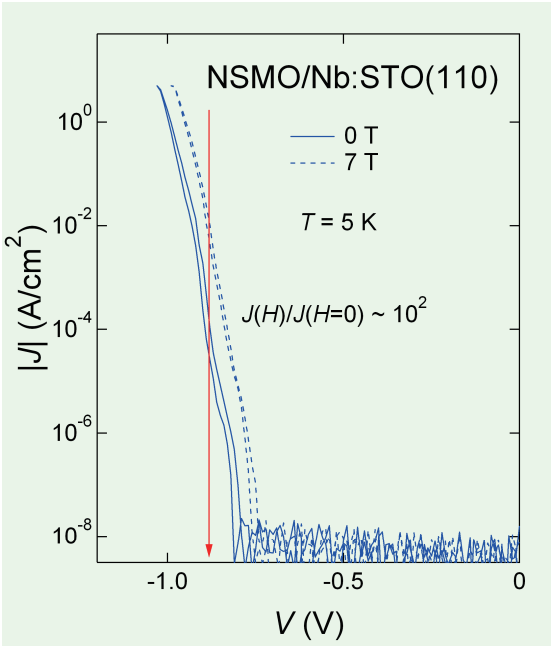


H-dependence

- The conductance was enhanced

  by magnetic field H

  → $J(H)/J(H=0) \sim 10^2$



Matsuno *et al.*, Appl. Phys. 92, 122104 (2008)

C-V characteristics

T-dependence

- $1/C^2$ changes linearly with V ($T \geq 200$ K)

  → $V_{BI} \sim 0.9$ eV

- $1/C^2$ shows nonlinearity ($T \leq 100$ K)

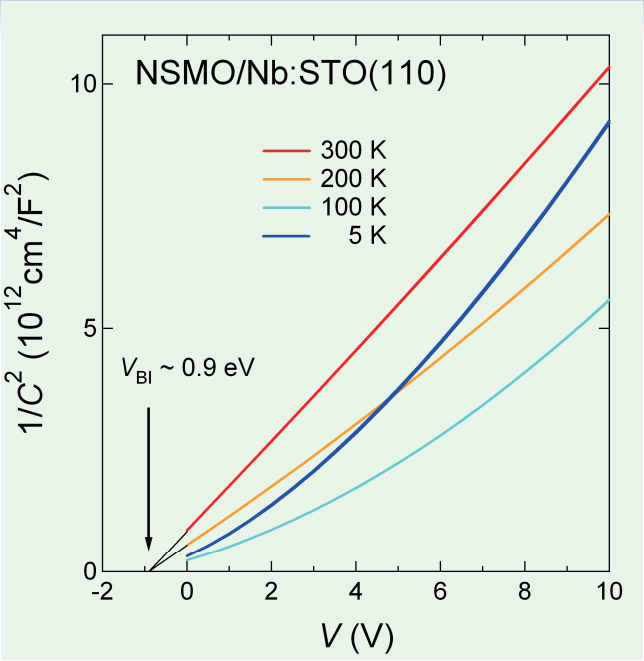
  ← Large E dependence of ε_{STO}

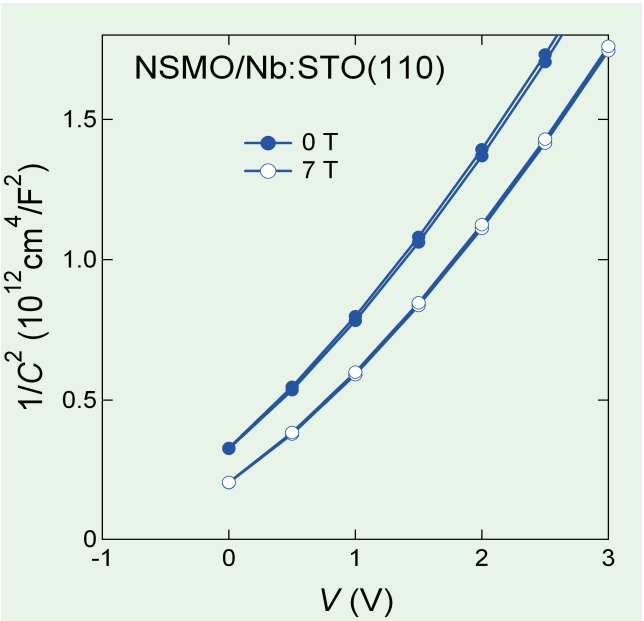
H-dependence

- Large positive magnetocapacitance

  at $T = 5$ K and 50 K

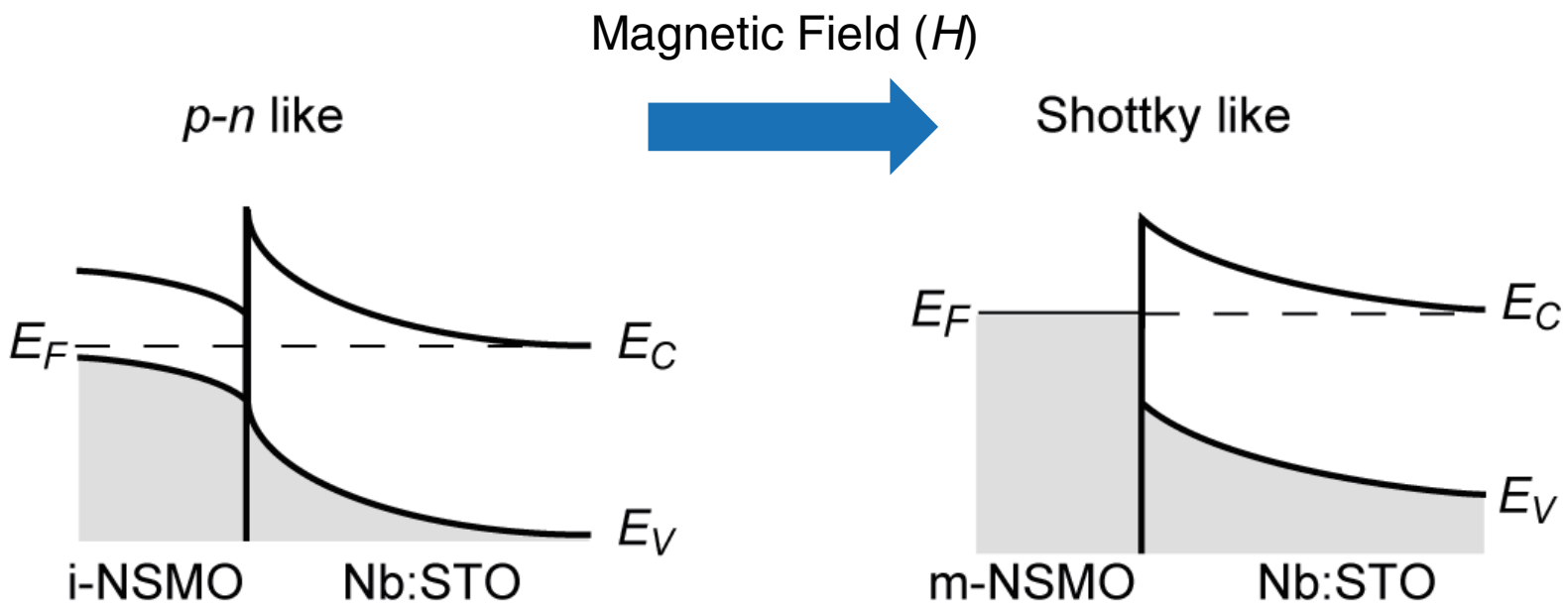
  ← Barrier potential is strongly modulated by H





Matsuno *et al.*, Appl. Phys. 92, 122104 (2008)

Prediction



Potential profile of depletion layer is modified by *H*

Change of *I-V* and *C-V* characteristics