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Exchange polarization coupling in wurtzite-perovskite oxide interfaces: New concepts for electronic device heterostructures?

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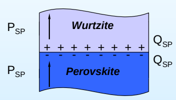
Interface: $BaTiO_3$/ZnO

Is there a polarization exchange coupling??

What is it?

Interaction of the wurtzite polarization (surface ionic charge) with the switchable ferroelectric perovskite polarization. This coupling should influence:



(I) Ferroelectric refractive index change Δn
(II) Ferroelectric phase transition
(III) Electrical properties of junctions
...

(I): Ann. Phys. 13, 61 - 62 (2004)
(II): Appl. Phys. Lett. 86, 091904 (2005)
B. Mbenkum, M.Sc. Thesis, Universität Leipzig Oct. 2004

(III): Metal-Ferroelectric-Semiconductor-Metal
Metal-Semiconductor-Ferroelectric-Semiconductor-Metal

This Poster !!

Growth and Structure

Pulsed Laser Deposition (PLD)

Heterostructures:
ZnO/BaTiO3/Pt/Si
ZnO/ BaTiO3/ZnO/Pt/Si
PLD conditions:

Layer	O_2 pressure [mbar]	Temperature [°C]	Laser Pulses	Laser Pulse Energy [mJ]
$BaTiO_3$	0.06	680	85000	600
ZnO	0.01	680	15000	600

DC-Magnetron Sputtering

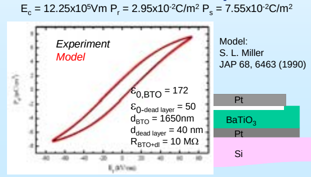
Top and bottom metal (Pt)-contacts

Sputter conditions:

Layer	Ar pressure [μbar]	Temperature [°C]
Pt	50	23

BTO Ferroelectric Properties

$E_c = 12.25\times10^5$Vm $P_r = 2.95\times10^{-2}$C/m² $P_s = 7.55\times10^{-2}$C/m²



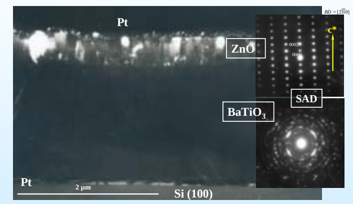
Structural Properties

$BaTiO_3$: polycrystalline, textured

ZnO: polycrystalline, c-axis texture; the column-like grains are always oriented with the c-axis parallel to the growth direction.

TEM dark field-image and SAD pattern

Pt/ZnO/BaTiO3/Pt/Si

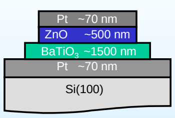


Energy Dispersive X-ray Analysis

Element	X-ray peaks	Weight %	Atomic %
$BaTiO_3$	O-K_α	20.10	59.60
	Ba-L_α	59.80	20.60
	Ti-K_α	20.00	19.80
ZnO	O-K_α	19.10	49.10
	Zn-K_α	80.90	50.90

Single Wurtzite-Perovskite Interface: Pt/ZnO/$BaTiO_3$/Pt/Si Polarization exchange coupling: Switchable-MFS thin film diode

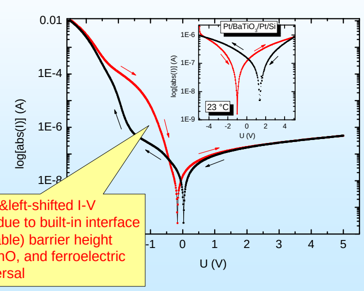
Structure

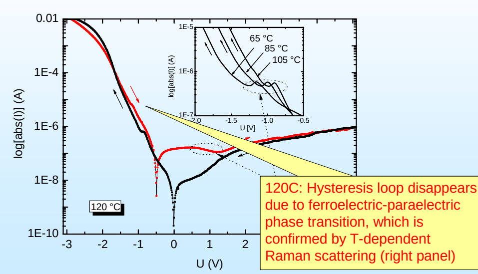


Current-Voltage Measurements

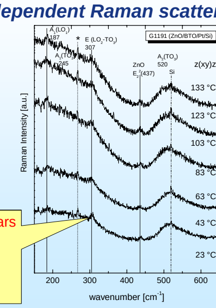
bias voltage path: -5 V -> +5 V -> -5 V
bias voltage step: 10 mV
bottom Pt-grounded

Room- and High-Temperature Current-Voltage Characteristics



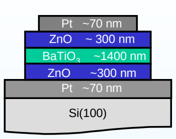


T-dependent Raman scattering



Double Wurtzite-Perovskite Interface: Pt/ZnO/$BaTiO_3$/ZnO/Pt/Si: Bistable capacitance with memory

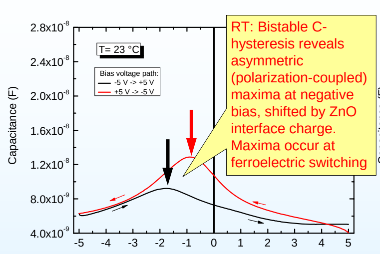
Structure

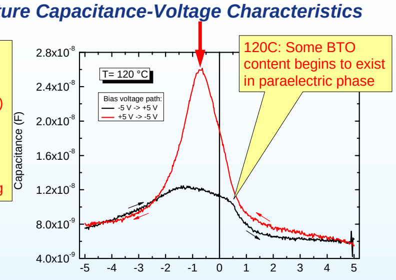


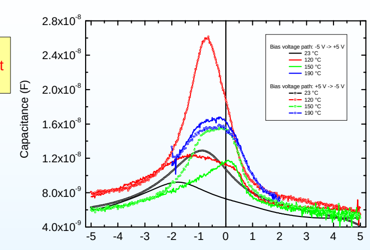
Capacitance-Voltage Measurements

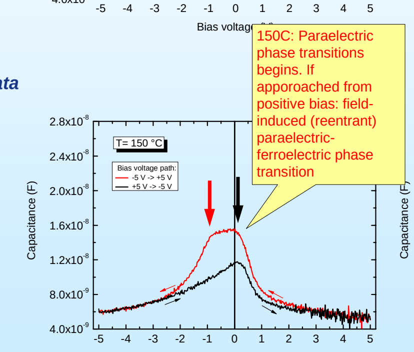
ac signal amplitude: 15 mV
ac signal frequency: 1 kHz
bias voltage path: -5 V -> +5 V -> -5 V
bias voltage step: 20 mV
bottom Pt-grounded

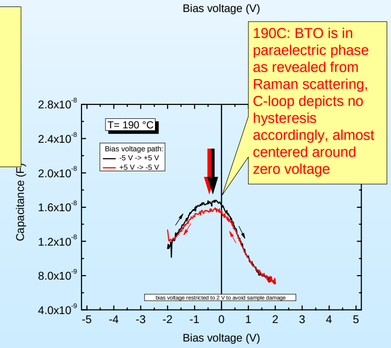
Room- and High-Temperature Capacitance-Voltage Characteristics



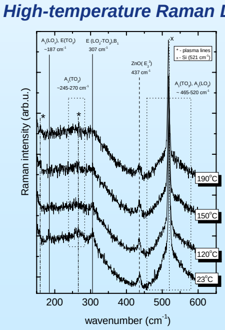








High-temperature Raman Data



Polarization exchange coupling: Bistable capacitance with memory

Asymmetric *C-V* loop with bistable maxima at negative bias-voltages.

- Depending on the bias-voltage sweep direction, the capacitance of the structure switches by more than e.g., 30% at 23°C and 100% at 120°C
- *C-V* hysteresis loop disappears at 190°C: diffuse ferroelectric to paraelectric phase transition due to ZnO interface and due to polycrystalline structure of $BaTiO_3$
- High-temperature Raman scattering data: confirmation of diffuse phase transition; ferroelectric-phase-sensitive $BaTiO_3$ phonon mode at 307 cm⁻¹ is present up to 190 °C
- Bistable ferroelectric domain orientation, switched by external bias voltage, causes large capacitance hysteresis with bistable magnitudes!

Possible use in addressable capacitance structures (memory)!

DPG, Dresden, March 2006

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