Electrooptic ellipsometry study of spontaneous polarization coupling in piezoelectric ZnO-BaTiO$_3$ heterostructures

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Polarization coupled interfaces

Is there a charge polarization coupling in BTO/ZnO?

Can this be used to determine the amount of the spontaneous polarization in ZnO?

We estimate the first experimental value for the spontaneous polarization in ZnO: $P_{sp} = 4 \mu$C/cm$^2$ [1]

Previous theory calculation: $P_{sp} = 5 \ldots 8 \mu$C/cm$^2$ [4]

Case I

Case II

Case III

Partialy Depleted ZnO

Fully Depleted ZnO

Conductive ZnO

Transition

$V_i = 0$

$V_i = 0$

$V_i = 0$

$$V = E_i d_j$$

$$V = E_i d_j + \frac{N d_j}{2\varepsilon_i} + E_f d_j$$

$$V = \alpha_b \frac{d_i}{\varepsilon_j} - P_{dz} \frac{d_i}{\varepsilon_j} - P_{dz} \frac{d_i}{\varepsilon_j} + \frac{N d_j}{2\varepsilon_i} + E_f d_j$$

Best fit Sawyer-Tower model parameters

Experimental model calculated data as a function of input voltage [V]

Influence of ZnO spontaneous polarization ($\times 10^{-1}$ C/m$^2$)

Initial polarization ($\times 10^{-2}$)$\mu$C/cm$^2$

Thickness of BaTiO$_3$ ($d_j$) 0.5 $\mu$m

Thickness of ZnO ($d_i$) 1.45 $\mu$m

Input frequency ($f$) 1.5 kHz

Sample resistance ($R_s$) 13 k$\Omega$

Dielectric constant of BaTiO$_3$ ($K_{BaTiO_3}$) 250

Dielectric constant of ZnO ($K_{ZnO}$) 8

Coercive field ($E_C$) 1.2 $\times 10^6$ V/m

Saturation polarization ($P_s$) 14.1 $\mu$C/cm$^2$

Remanent polarization ($P_r$) 6.35 $\mu$C/cm$^2$

Intrinsic concentration in ZnO ($N_i$) 5.5 $\times 10^{20}$ m$^{-3}$

Built-in voltage in the sample ($V_{bi}$) -1.03 V

Spontaneous polarization in ZnO ($P_{sp}$) -4.0 $\mu$C/cm$^2$

Influence of ZnO layer thickness ($\mu$m)

Electrooptic ellipsometry study of piezoelectric properties

Wavelength averaged electrooptic changes

Calculated data

Calculated data

The coupling between the non-switchable lattice charge of wurtzite structure (ZnO) and the switchable ferroelectric polarization $P_{sp}$ in perovskite structure (BaTiO$_3$) is interesting [1,2].

Here we report on electrical and electrooptic measurements of Pt/BaTiO$_3$/ZnO/Pt heterostructures.

We observe index of refraction and piezoelectric thickness hysteresis behavior concordant with electrical polarization hysteresis.

The simulations to the right depict electric Sawyer-Tower and BTO polarization hysteresis loops for our ZnO/BTO heterostructure. The model parameters are listed below.

Samples are prepared by Pulsed Laser Deposition, and subsequent masking with ohmic Pt back and front contacts.

Electric Sawyer-Tower and electrooptic ellipsometry measurements were performed on contacts and near contacts, respectively.

References:
[4] Bernardini et al., APL 86, 091904 (2005);

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