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Reasons for the weak manifestation of the field effect in metal-$Ba_{1-x}Sr_xTiO_3$-Si structures

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Solid solutions of barium-strontium titanate ($Ba_{1-x}Sr_xTiO_3$ or BST) have ferroelectric properties above the room temperature, and their dielectric constant remains sufficiently high in the paraelectric phase. Despite lengthy (several decades) studies, there are still no reports of operating conducting surface channels of minority charge carriers in Si in structures based on these ferroelectrics. In this work, on the basis of a developed one-dimensional model of the high-frequency (HF) impedance of Ni-BST-Si objects with an insulator in the paraelectric phase, the reason for the weak manifestation of the field effect is revealed and ways of its elimination are discussed. Let $C_{SE}(V_{SE})$ be the RF capacitance voltage characteristic of the metal-BST-metal structure with exactly the same ferroelectric layer as in Ni-BST-Si. Then from the RF impedance model follows the inequality:

$$\left\{\left[1-\frac{\left(C+\dfrac{\sigma^2}{\omega^2 C}\right)}{C_s}\right]\left[\frac{\left(C+\dfrac{\sigma^2}{\omega^2 C}\right)}{C_{SE}}+\frac{\left(C+\dfrac{\sigma^2}{\omega^2 C}\right)}{C_s}-1\right]\right\}^{1/2}<\frac{\sigma}{\omega C}, \qquad (1)$$

where C and σ are the high-frequency capacitance and the conductivity of the Ni-BST-Si sample, is ω the cyclic frequency of the high-frequency signal, C_s is the capacity of the charged layer in Si. In Figures 1 and 2 show characteristics, respectively, of the structures Ni-$Ba_{0.8}Sr_{0.2}TiO_3$-Si and Ni-$Ba_{0.8}Sr_{0.2}TiO_3$-Pt with an insulator thickness of 350 nm, measured at 1 MHz and 121°C.

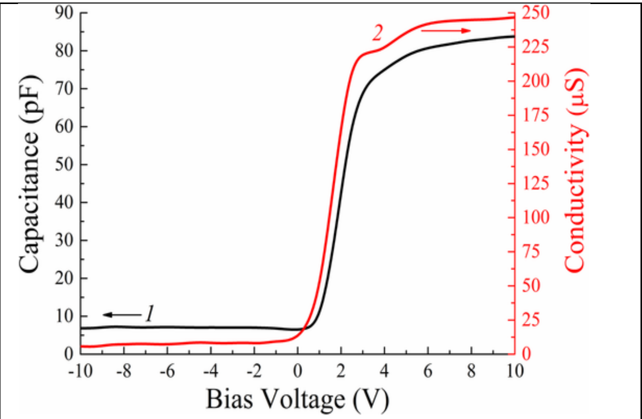

Fig. 1.

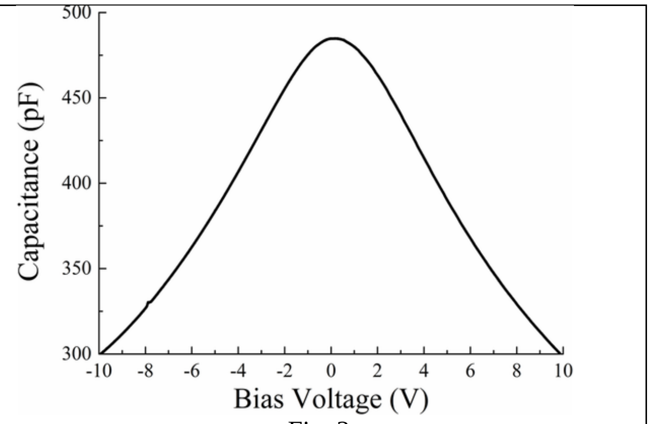

Fig. 2.

Under experimental conditions $C_{SE} >> C$ and $\sigma / \omega C << 1$, therefore, inequality (1) follows $C \approx C_S$. The capacity of a semiconductor in the flat band state is C_{sfb} = 9.17 pF; therefore, the band bending in Si is significantly limited: less than 0.033 V at depletion and 0.165 V at enrichment. Thus, the overwhelming part of the external voltage drops across the insulator; almost complete screening of the polarization of the ferroelectric gap in the metal-BST-Si structure occurs due to the recharging of surface electron traps in the interphase layer between BST and Si. Based on the range of changes in external voltage, their concentration should be at least 10^{14} cm^{-2}. To eliminate the activity of traps in the interfacial layer, it is natural to use the experience gained in planar silicon technology on the passivation of surface localized electronic states. The termination of the recharging of centers in the interfacial layer will make it possible to create transistors based on metal-BST-Si with a working surface channel of minority charge carriers and will ensure the construction of high-quality cells of non-volatile memory FeRAM.

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