Giant tunneling electroresistance in ferroelectric tunnel junctions successfully obtained in a newly suggested scheme

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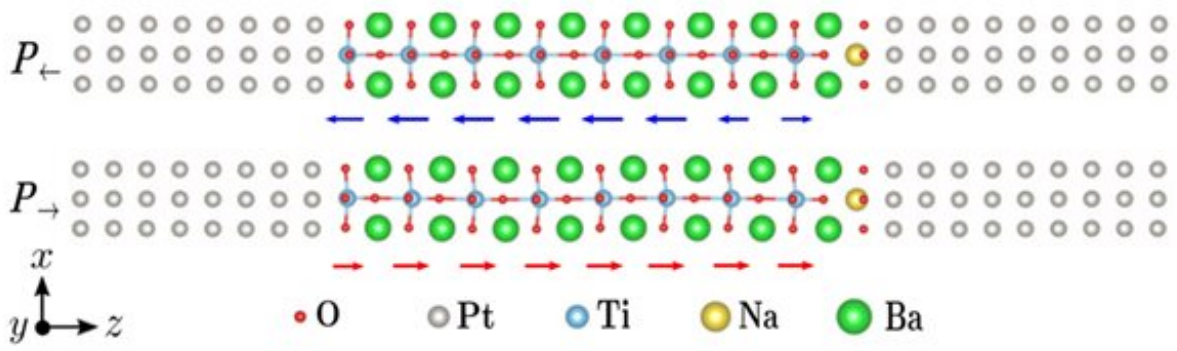


The schematic diagrams of the atomic structures in the left and right polarization states of NaTi-FTJ. Credit: Xiao Wei

Recently, in a paper published in *Physical Review Applied*, a research team from the Hefei Institutes of Physical Science (HFIPS), Chinese Academy of Sciences (CAS) studied the interfacial control of transport properties of perovskite oxide ferroelectric tunnel junctions (FTJs) and proposed a new scheme to achieve a giant tunneling electroresistance (TER) in FTJs.

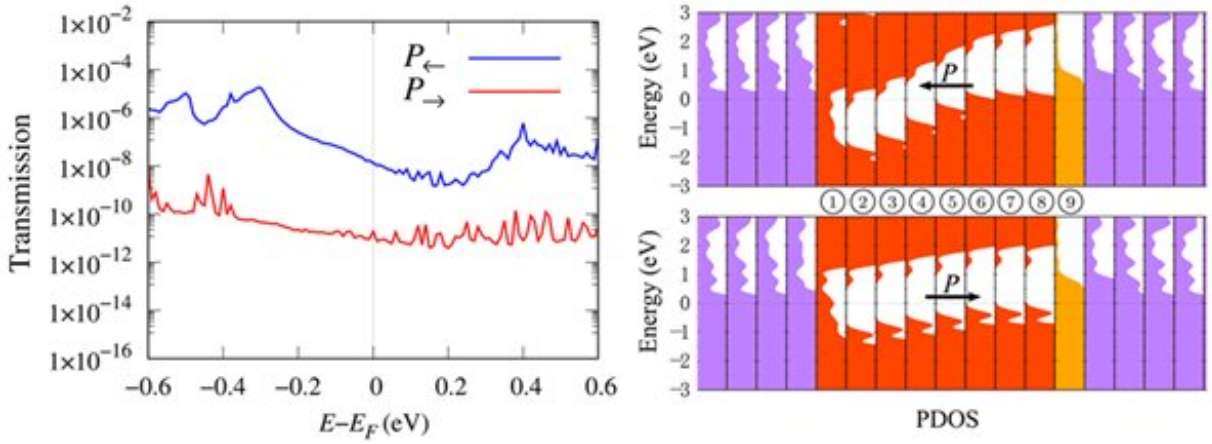
According to Zheng Xiaohong, leader of the team, a TER ratio of up to 10^5 % was obtained by introducing a negative polar atomic layer at one

of the interfaces of the symmetric Pt/$BaTiO_3$/Pt FTJ.

FTJ is a tunnel junction in which a thin ferroelectric film is sandwiched between two metal electrodes. The resistance is highly dependent on the polarization direction of the ferroelectric barrier. Two greatly different states with high and low resistances respectively can be obtained by reversing the polarization direction with an external electrical field.

FTJs have important applications in non-volatile random access memories. With advantages of high data storage density, fast read/write speed and low power consumption, they have attracted extensive research interest as memory elements. The difference between the high and low resistance states is usually characterized by TER ratio. Therefore, how to obtain a high TER ratio is always one of the key issues in the study of FTJs.

In this research, scientists proposed a new scheme to realize giant TER ratios by introducing a negative polar atomic layer at one interface of the FTJ.



The k-averaged transmission and layer-resolved density of states of two polarization states of NaTi-FTJ. Credit: Xiao Wei

In the symmetric Pt/$BaTiO_3$/Pt FTJ, a negative NaO_2 or LiO_2 interface is formed by replacing Ti with Na or Li atoms at the right interface of Pt/$BaTiO_3$/Pt tunnel junction. Then a 10^5 % TER ratio was achieved due to this additional NaO_2 or LiO_2 layer.

The mechanism is rooted in the great difference in the potential change in the ferroelectric barrier arising from the negative polar interface in the two polarized states.

When the ferroelectric barrier is left polarized, the bands of the barrier at each atomic layer increase from left to right. Meanwhile, due to Coulomb repulsion, the negatively charged NaO_2 or LiO_2 interface further pushes up the bands of the barrier, and near the right interface region, the valence band maximum (VBM) rises above the Fermi energy, leading to partial metallization.

In the right polarization state, although the Coulomb repulsion at the NaO_2 or LiO_2 interface still exists, the band of the ferroelectric barrier itself decreases from left to right. Due to the cancelation between them, the valence band distribution in the whole barrier is relatively flat and the VBM is always below the Fermi energy, without the occurrence of partial metallization. The occurrence and disappearance of partial metallization in the two polarization states change the effective barrier width significantly and lead to the low and high resistance states, with a giant TER ratio achieved subsequently.

The study indicates that a negatively charged polar interface based on interfacial substitution is a feasible scheme to achieve large TER ratio in

FTJs and provide important reference for the design of high-performance FTJs.

More information: Wei Xiao et al, Giant Tunneling Electroresistance Induced by Interfacial Doping in Pt/BaTiO3/Pt Ferroelectric Tunnel Junctions, *Physical Review Applied* (2022). DOI: 10.1103/PhysRevApplied.17.044001

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