Polarization-switching pathway determined electrical transport behaviors in rhombohedral BiFeO3 thin films

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Abstract: **We investigate the polarization-switching pathway-dependent electrical transport behaviors in rhombohedral-phase $BiFeO_3$ thin films with point contact geometry. By combining conducting-atomic force microscopy and piezoelectric force microscopy, we simultaneously obtained current-voltage curves and the corresponding domain patterns before and after the polarization switching. The results indicate that for (001)-oriented film, the abrupt current (due to polarization reversing) increases with the enhanced switching voltage for 109° and 180° switching events. More importantly, the abrupt current can be further improved in (110)- and (111)-oriented thin films, which benefits from the stronger modulation of interfacial Schottky barrier by the enhanced out-of-plane polarization magnitude. The current on-off ratio obtained in a ~20 nm thick (111)-oriented $BiFeO_3$ thin film at a read voltage of ~3V exceeds (~6 × 10^5)%, which is close to the result from a previous report on ultrathin tetragonal $BiFeO_3$ thin film.**

Introduction

Ferroelectric tunneling junctions (FTJs) have attracted intensive research interest in the past few decades due to the fundamental physics and potential application in non-volatile ferroelectric memories and solid-state synapses with non-destructive and sub-nanosecond read-out process. Such phenomena take advantage of both the ferroelectric polarization control of the tunneling barrier, and the stabilization of the ferroelectric domain at the nano-meter scale. To date, the main focus on FTJs is to enhance the tunneling electroresistance (TER) effect by regulating the tunneling barriers, which has made great progress by designing metal-ferroelectric-semiconductor heterostructures, asymmetric metallic electrodes, selecting oxide semiconductor with insulator-to-metal transition as the imbedded layer, taking advantage of optical field or flexoelectric field, etc. Nevertheless, one critical point is that the thickness of the ferroelectric oxide layer in those FTJs need to be shrank to shrunk 2-3 unit cells to decrease the tunneling barrier, which would induce a large leakage current and low TER effect. In addition, numerous ferroelectric materials would suffer from the polarization degradation in ultrathin films, which endows FTJs with broad commercial applications and also prevents deep understanding of the intrinsic polarization-related ferroelectric tunneling behaviors.

Results and discussion

Figure. 1 Epitaxial growth and ferroelectric properties of (001)-oriented R-phase BFO thin film.

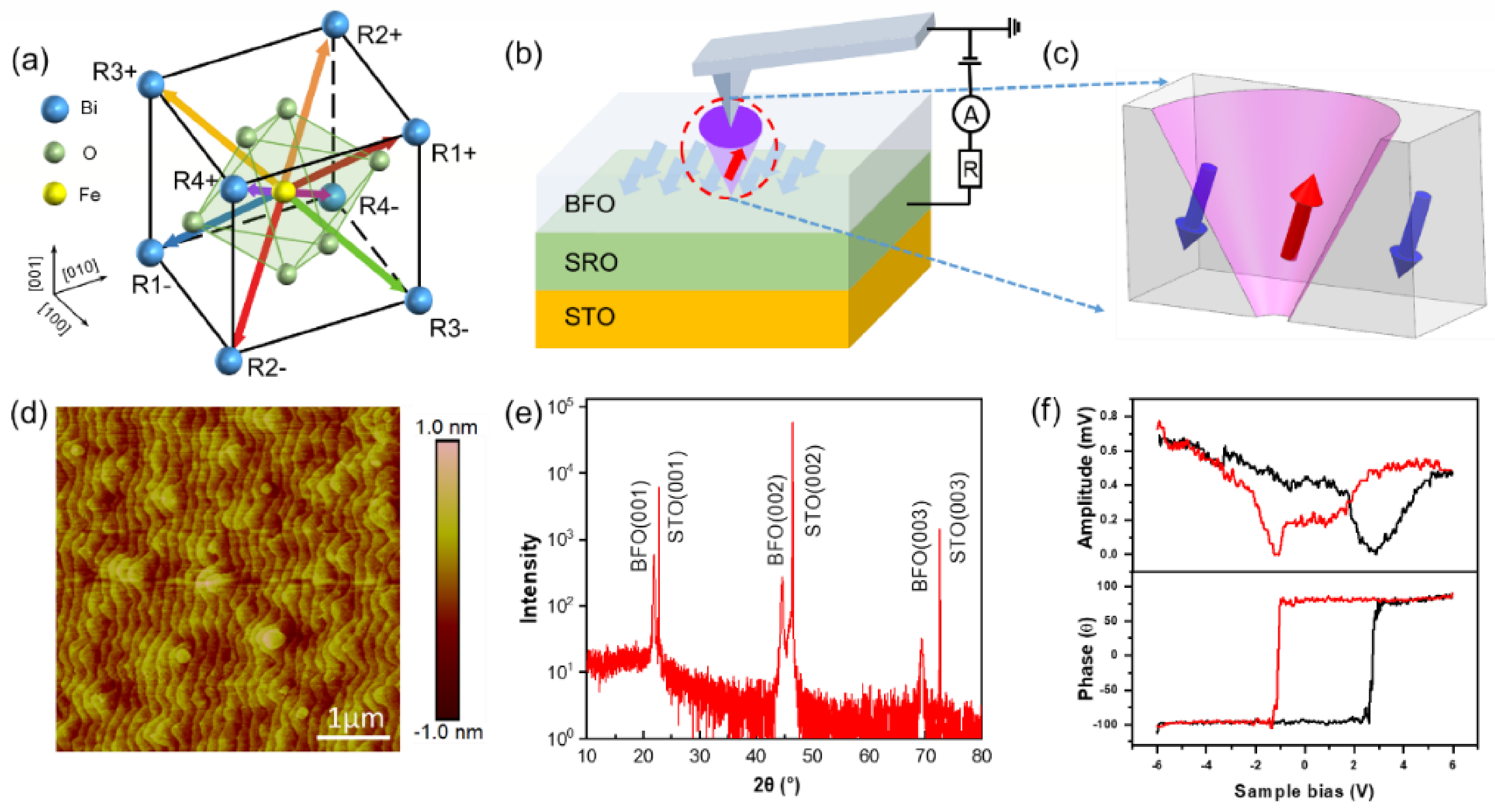


Figure. 2 Polarization-switching pathway-dependent electrical transport behaviors in (001)-oriented R-BFO thin film.

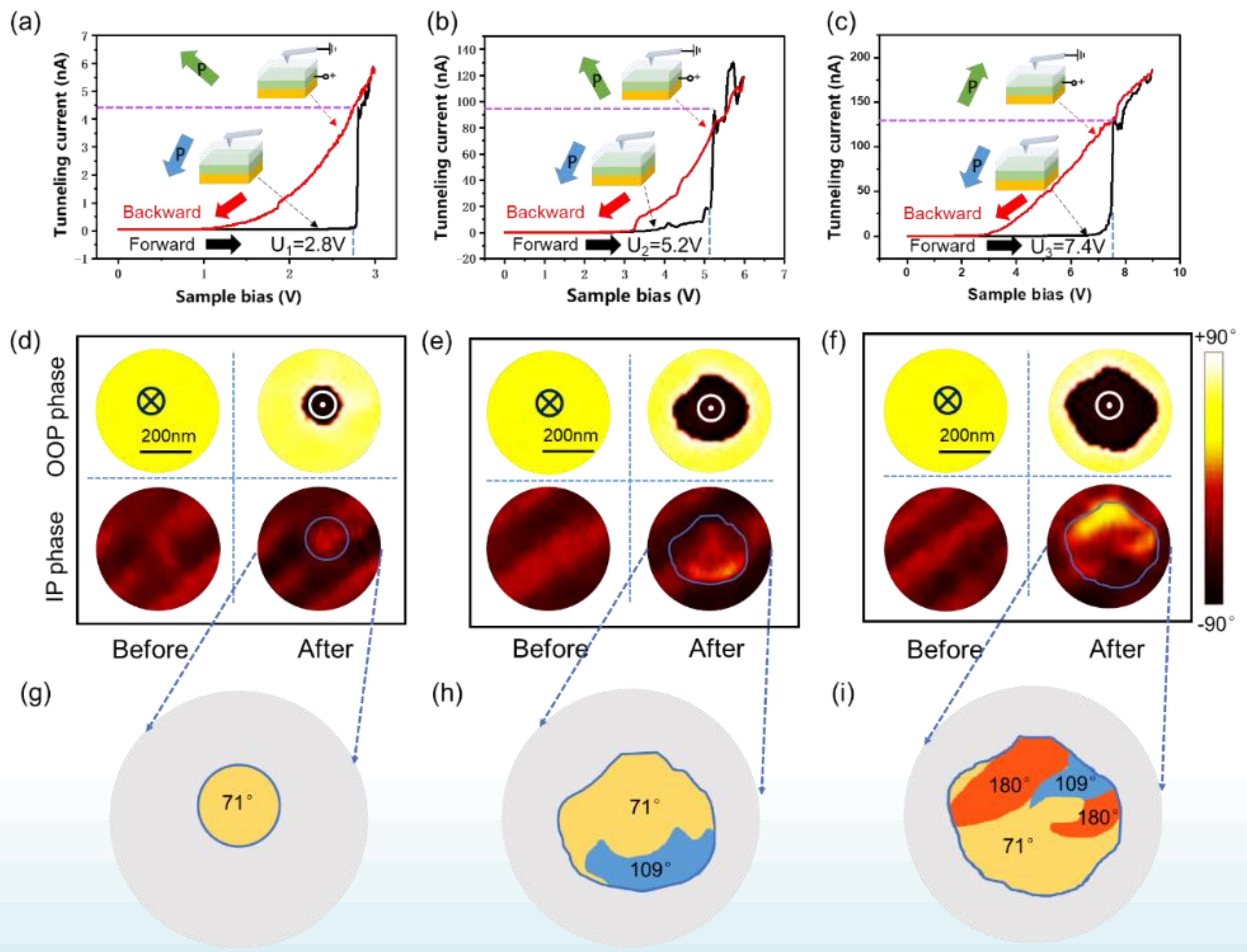


Figure. 3 Various switching barrier for 71°, 109° and 180° switching events respectively.

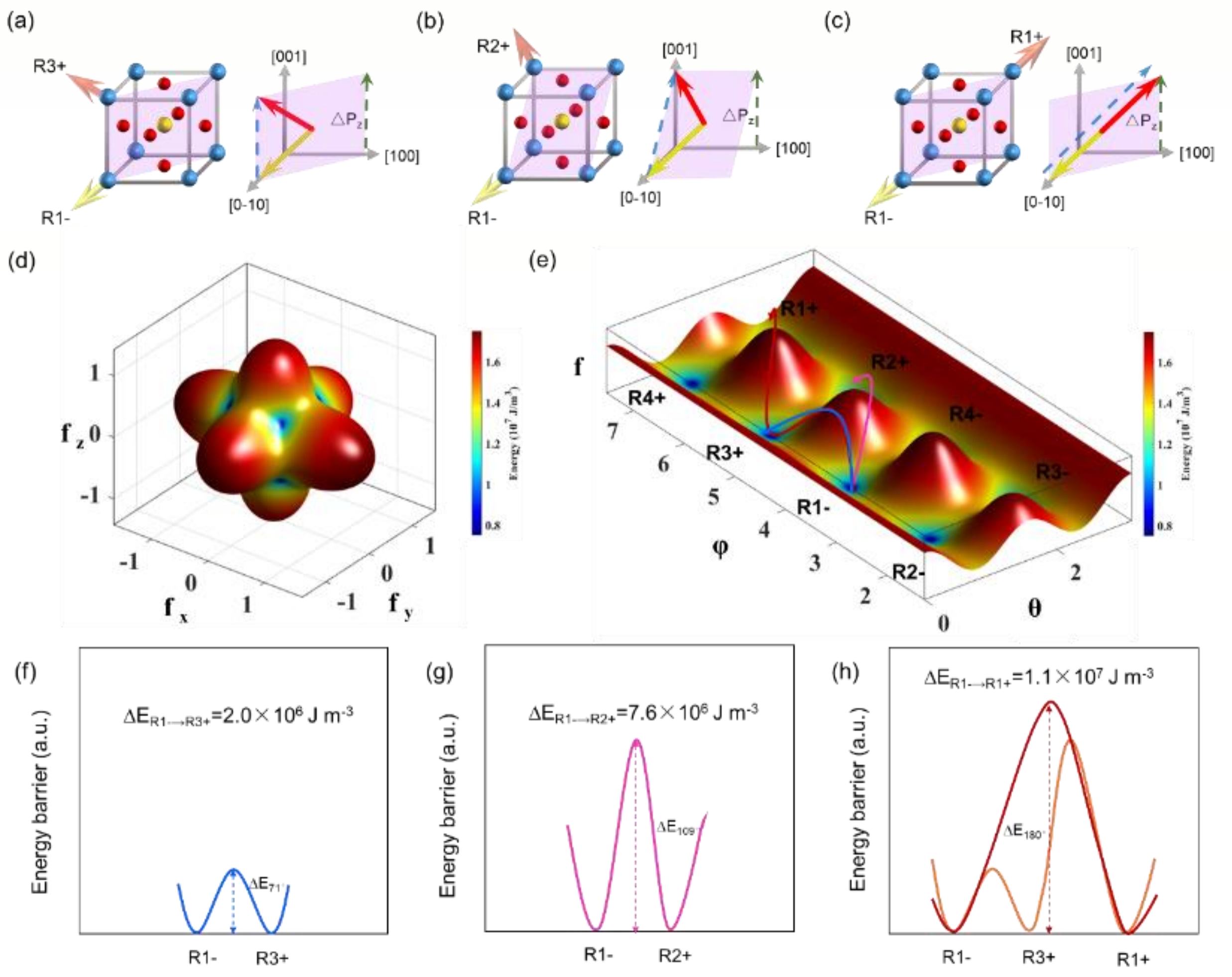
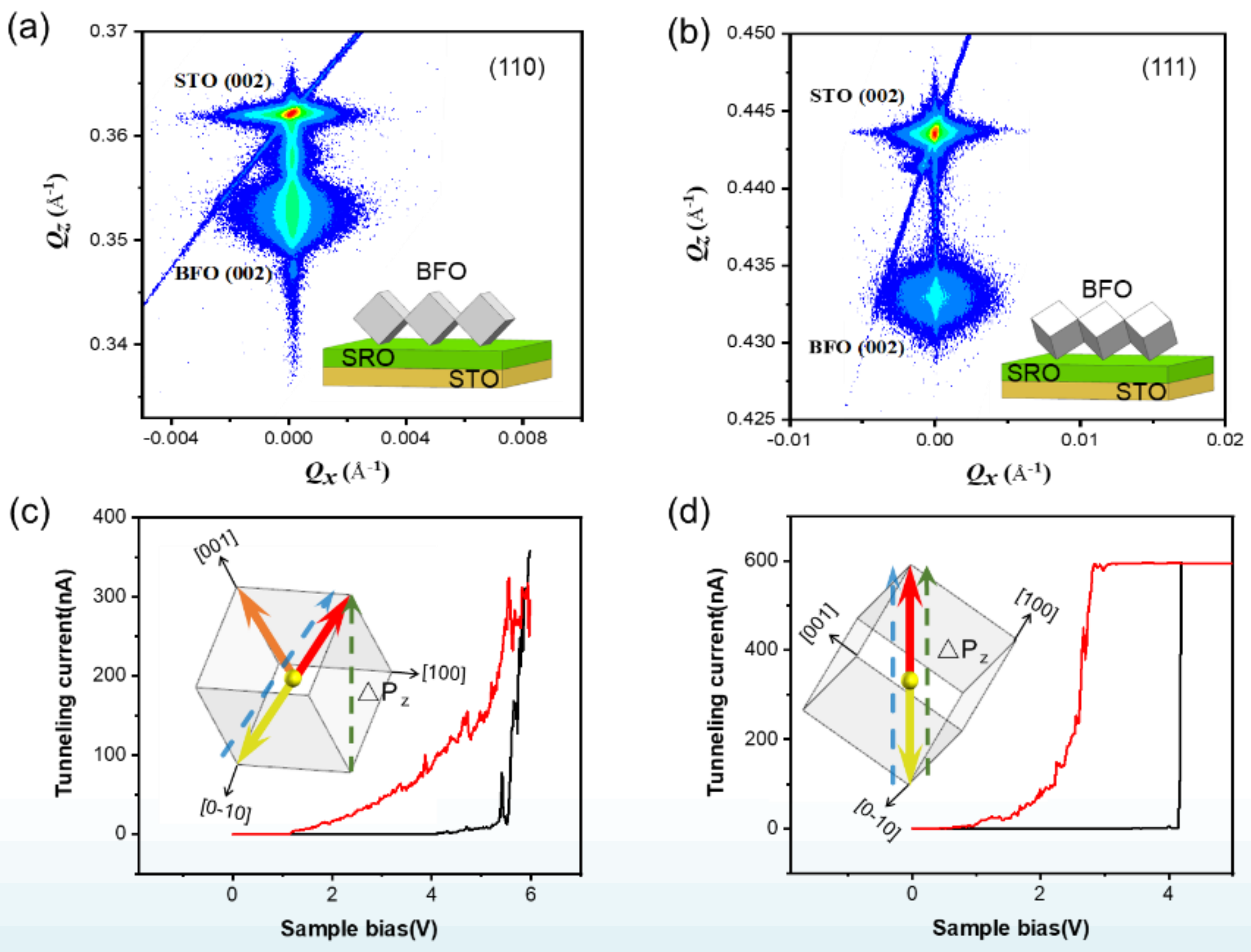


Figure. 4 Electrical behaviors in (110)- and (111)-oriented BFO thin films.



Conclusion

- **In summary, we discussed the correlation between polarization-switching pathway and the local electrical transport behaviors in R-phase BFO thin films.**
- **In the (001)-oriented BFO thin film, the abrupt current is mainly modulated by the switching voltage, which gradually increases for 71°, 109° and 180° switching events due to the increase in the switching barrier.**
- **In addition, the abrupt current can be further enhanced by designing (110)- and (111)-oriented BFO heterostructures, which can be attributed to the relatively large magnitude tunning of Schottky barrier at the top and bottom interfaces of the ferroelectric capacitors by the enhanced polarization projection along the electrical transport direction.**

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