Realization of a ferroelectric memristor in a topological semimetal

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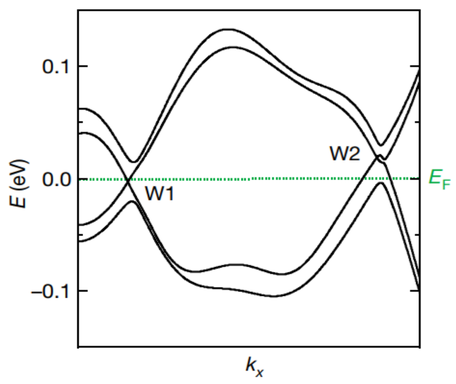
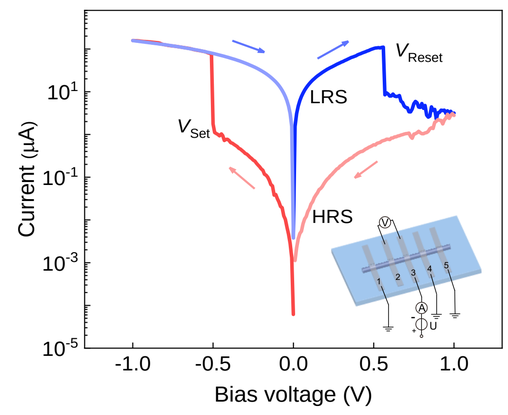
Introduction

Ferroelectricity is generally incompatible with systems featuring metallicity due to the screening effect of free carriers. So far, ferroelectric topological materials have only been found in limited cases, such as SnTe[1] and WTe_2[2]. In this work, we find that the surface state of topological semimetal material $(TaSe_4)_2I$ presents out-of-plane ferroelectric polarization due to surface reconstruction. And we successfully construct a prototype ferroelectric memristor based on $(TaSe_4)_2I$. The result of first-principles calculations reveals that there is a strong interplay between ferroelectricity and band topology.

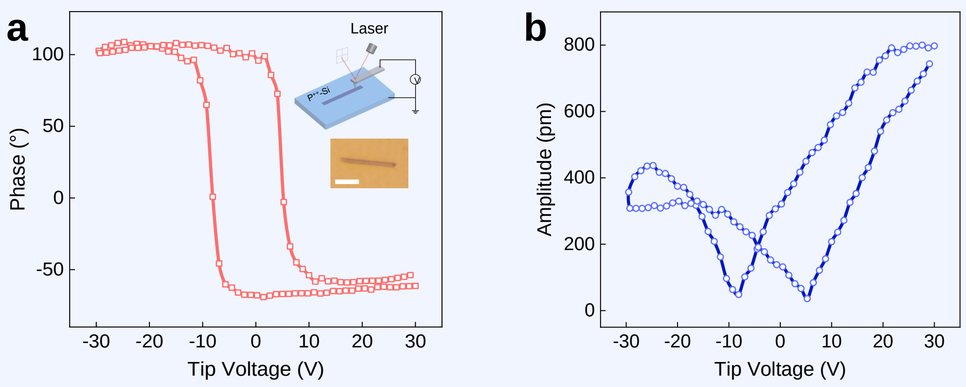


Band structure of $(TaSe_4)_2I$[3].

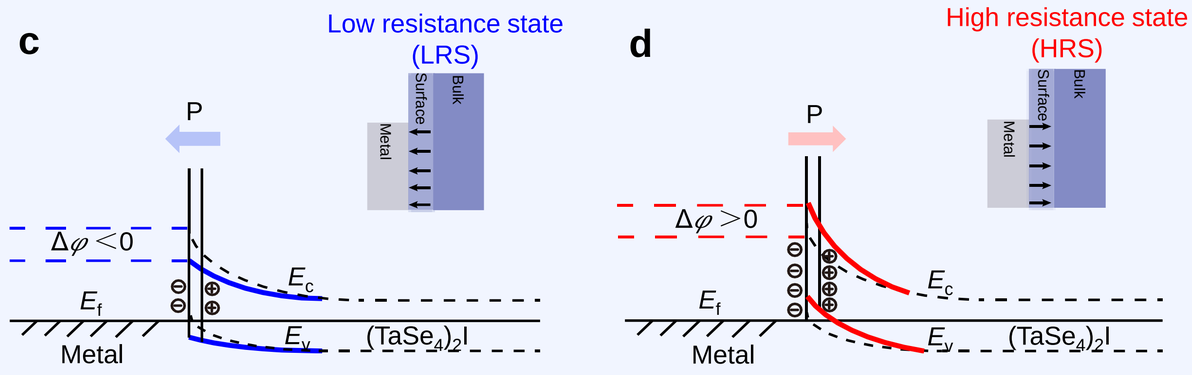


I-V curves of the $(TaSe_4)_2I$ memristor at 120 K.

Memristive switching by ferroelectric polarization

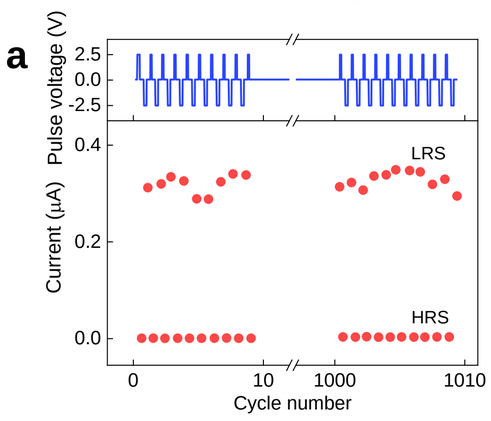


a-b, PFM phase (**a**) and amplitude (**b**) hysteresis loop of a $(TaSe_4)_2I$ thin nanoribbon on p^{++}-Si at room temperature.

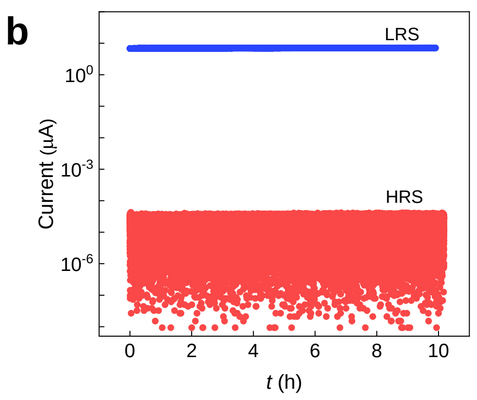


c-d, Schematic illustration of resistance switching mechanism. The energy band at the interface of the contact is modified by the out-of-plane ferroelectric polarization.

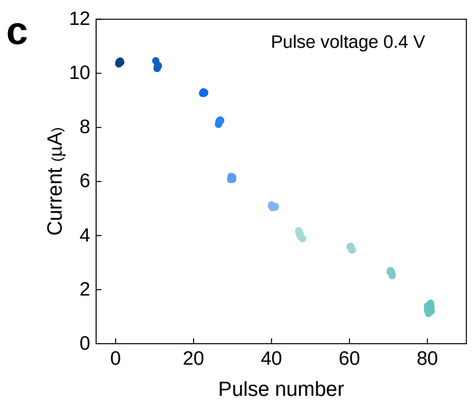
The device performance of the $(TaSe_4)_2I$ memristor



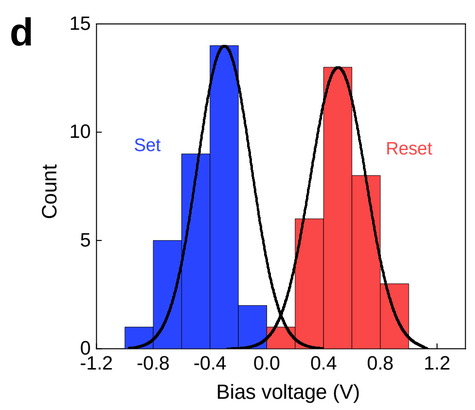
Endurance properties of the device.
Endurance over 10^3 cycles.



Retention of the HRS and LRS currents.
Retention over 10h.

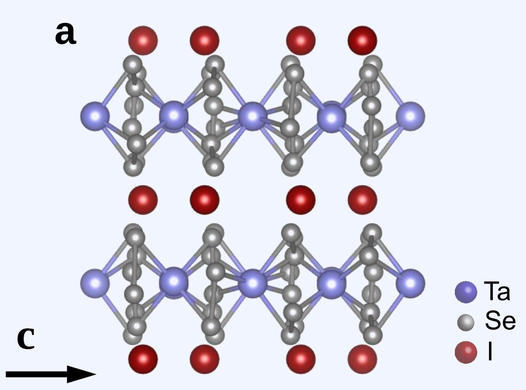


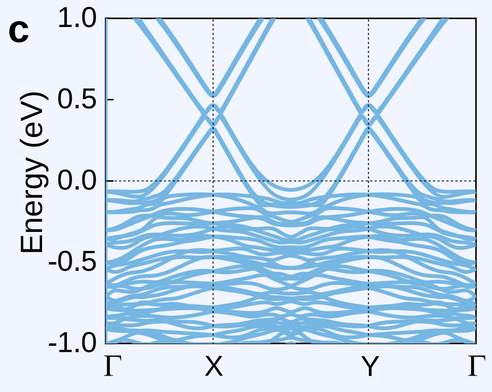
Multilevel non-volatile current states as tuned by different pulse numbers.

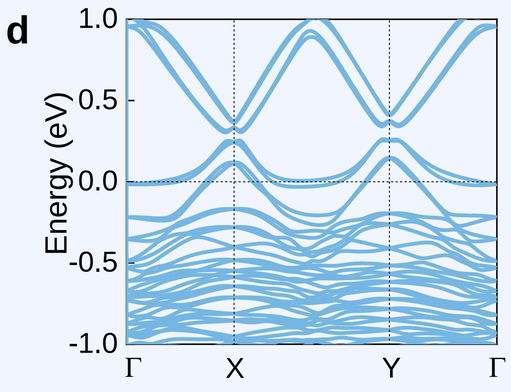


Statistical distribution of the Set/Reset voltages.

Origin of ferroelectricity in $(TaSe_4)_2I$







a-b, Side view of the $(TaSe_4)_2I$ (110) surface in **a,** pristine paraelectric phase and **b,** ferroelectric phase.

c-d, The band structure of $(TaSe_4)_2I$ surfaces in **a** and **b**.

Conclusion

1. The ferroelectricity in $(TaSe_4)_2I$ is evidenced by a hysteresis loop in PFM measurement.
2. We successfully realize the resistance switching of metal-$(TaSe_4)_2I$ contact with non-volatile property.
3. Theoretical calculation shows that the ferroelectricity in $(TaSe_4)_2I$ results from the surface reconstruction.

Reference:
1、Chang, K. *et al. Science* 353, 274–278 (2016).
2、Fei, Z. *et al. Nature* 560, 336–339 (2018).
3、Gooth, J. *et al. Nature* **575**, 315–319 (2019).