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Direct visualization of edge state in even-layer $MnBi_2Te_4$ at zero magnetic field

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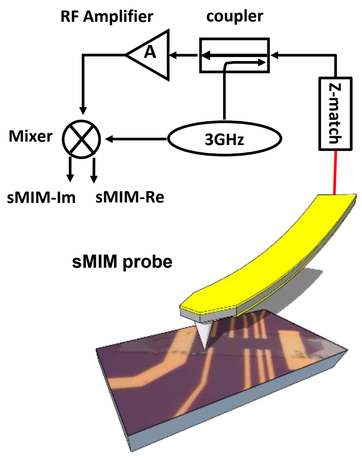
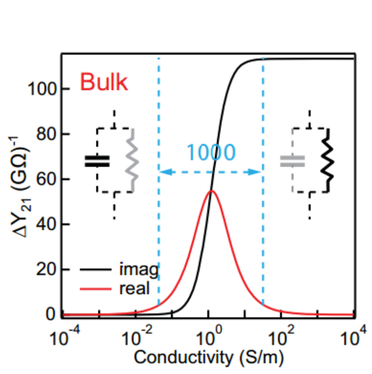
Technique and material

Scanning Microwave Impedance Microscopy (sMIM)

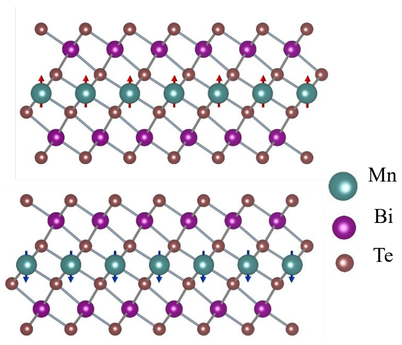




sMIM response curve

- ***AFM-based near field scanning probe***
  - Probe the local conductivity/dielectric variation
  - Non-contact and high spatial resolution ~50 nm
- ***Suitable for study of topological materials (bulk vs. edge)***

Antiferromagnetic topological insulator (AFM-TI): $MnBi_2Te_4$

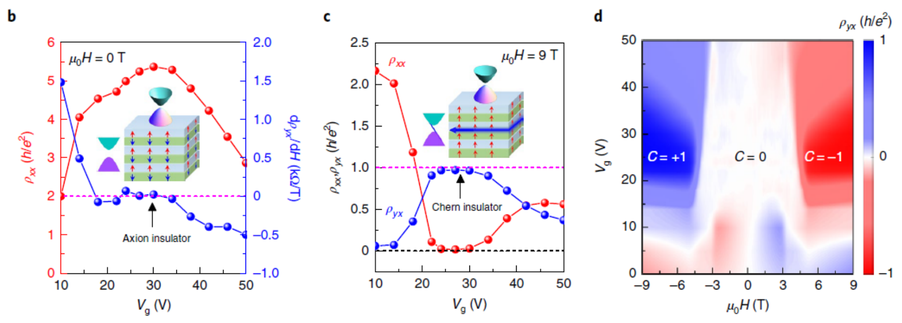


$MnBi_2Te_4$ with AFM order

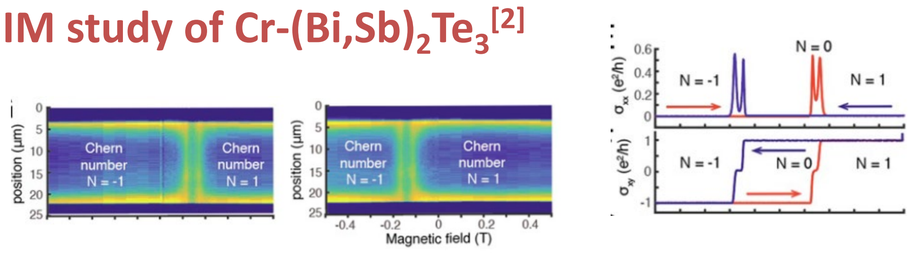
- ***Stoichiometric TI with intrinsic magnetism***
  - Intricate interplay between magnetism and topological order
- ***Even-layer $MnBi_2Te_4$ flakes***
  - Chern insulator/Axion insulator at high (zero) fields

Motivation

Transport study of 6-SL $MnBi_2Te_4$[1]



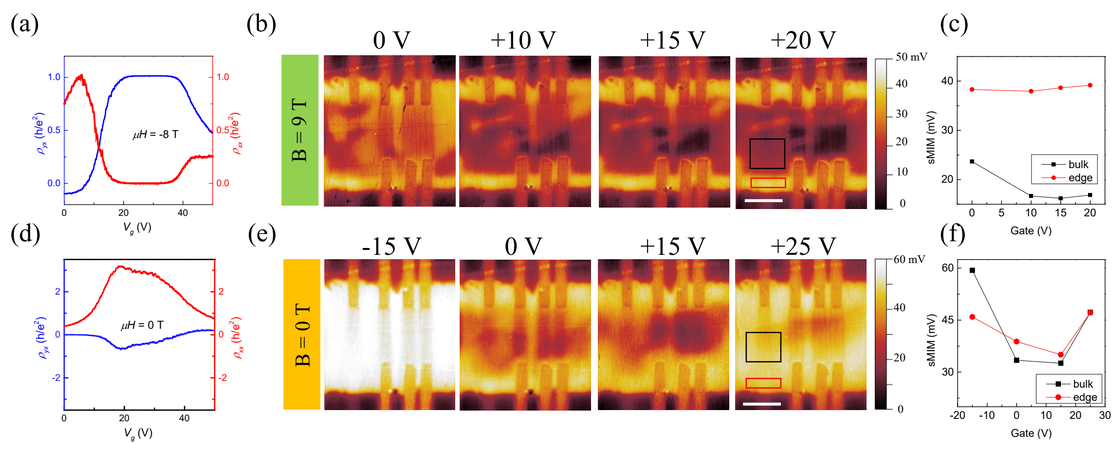
sMIM study of Cr-$(Bi,Sb)_2Te_3$[2]



- ***Transport study reveals Axion to Chern insulator transition in 6-SL $MnBi_2Te_4$***
- ***sMIM reveals the absence (existence) of edge states in Axion (Chern) insulator state in Cr-doped $(Bi,Sb)_2Te_3$***

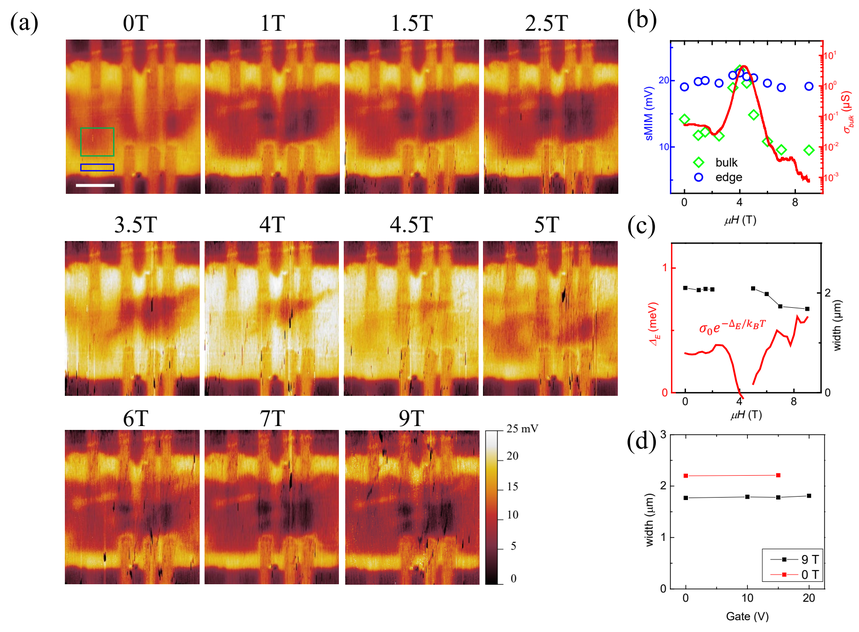
Results

Gate voltage dependent sMIM imaging



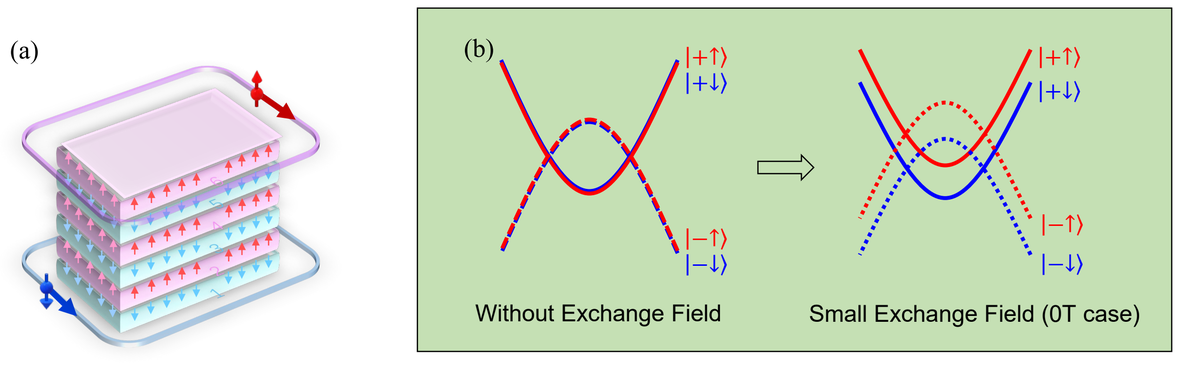
- ***Direct visualization of topological edge state in Chern insulator phase at high fields***
- ***Another edge state uncovered at zero magnetic field***

Magnetic field dependent sMIM imaging



- ***Direct visualization of insulator-to-metal transition (IMT) for the bulk***
- ***Persistent edge state upon the transition***

Physical origin of edge state at zero field



- ***Surface hall current underlying half-quantized surface Hall effect in three-dimensional TI***
- ***Time reversal symmetry broken quantum spin Hall state***

Conclusions

- ✓ An magnetic field driven Axion to Chern insulator transition was directly visualized with a bulk IMT
- ✓ A persistent edge state was revealed from Chern to Axion insulator phase calling for new understandings

References

[1] C. Liu, *et al*. "Robust axion insulator and Chern insulator phases in a two-dimensional antiferromagnetic topological insulator" *Nature Materials* **19**, 522 (2020)

[2] M. Allen, *et al*. "Visualization of an axion insulating state at the transition between 2 chiral quantum anomalous Hall states" *PNAS* **116**, 14511 (2019)