Bulk Superconducting Phase with a Full Energy Gap in the Doped Topological Insulator $Cu_xBi_2Se_3$

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Yoichi Ando

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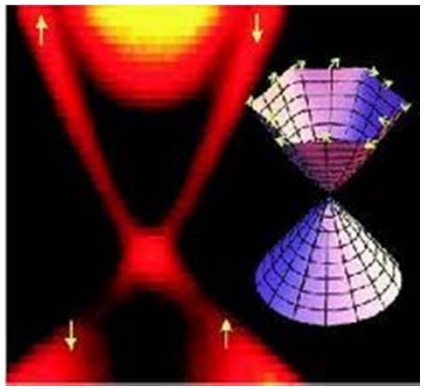
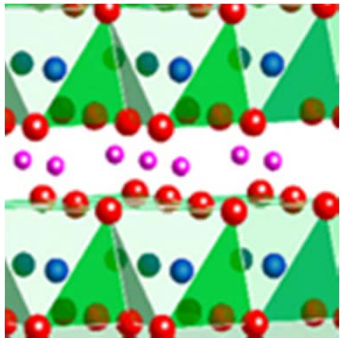


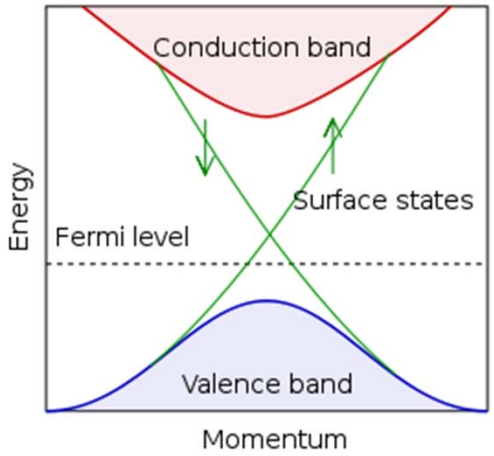


Outline

- Summary of the paper
- Comparisons between results in this paper with those in other papers
- Summary of conclusions made by the authors and us
- Critical evaluation of the paper

Topological Insulator: A New State of Matter

- In the past few years, topological insulators have been attracting a lot of interest as a newly discovered state of matter.



- A topological insulator is a material that behaves as an insulator in its interior or bulk while permitting the movement of charges (metallic) on its surface. [From Wikipedia]

$Cu_xBi_2Se_3$ as a Topological Superconductor

- This paper investigates the superconductivity of Cu-intercalated topological insulator Bi_2Se_3, i.e. $Cu_xBi_2Se_3$.

- Resistivity, magnetization and specific-heat of this material are measured, producing some fascinating results.

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Previous works for $Cu_xBi_2Se_3$

- Experimental:

Superconductivity was observed (at T_c =3.8 K) in the Cu–intercalated topological insulator $Cu_xBi_2Se_3$ [Y.S. Hor *et al*.,2010; L. A. Wray *et al*. 2010]

- Theoretical:

It was proposed that $Cu_xBi_2Se_3$ is a potential candidate for a topological superconductor [L. Fu & E. Berg, 2010].

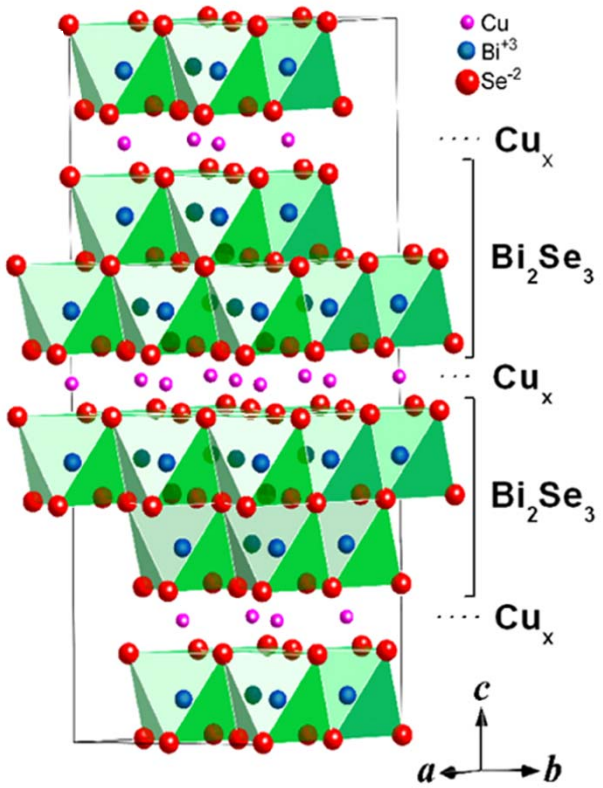

Fig. The crystal structure of Cu intercalated Bi_2Se_3 [Y.S. Hor et al., 2010]

Comparison of our paper's result with those of previous works

- Our paper reports zero resistivity and a magnetic shielding fraction exceeding 40% in $Cu_xBi_2Se_3$

- In the previous results from the groups of Y.S. Hor and L. A. Wray, the resistivity remained finite and shielding fraction of only up to 20%

Data measured in our paper [M. Kriener *et al.*, 2011]

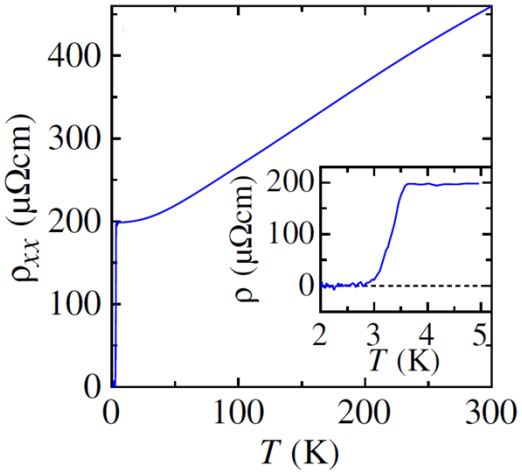

Fig. ρ_{xx}(T) data of the $Cu_{0.29}Bi_2Se_3$ sample.

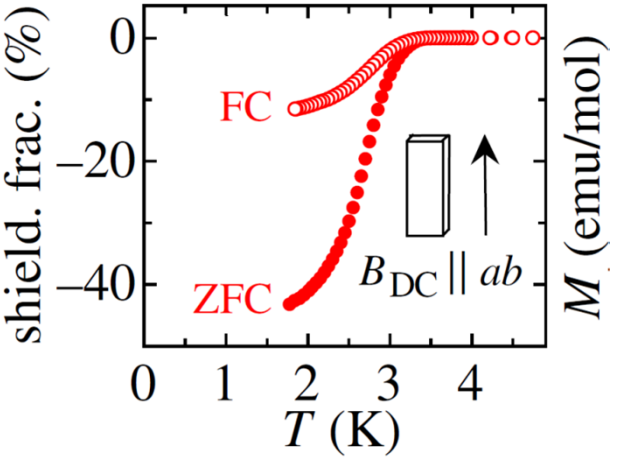

Fig. Temperature dependence of the apparent shielding fraction of $Cu_{0.29}Bi_2Se_3$ measured in B = 0.2 mT ∥ ab.

Data measured in previous paper [Y.S. Hor *et al.*,2010]

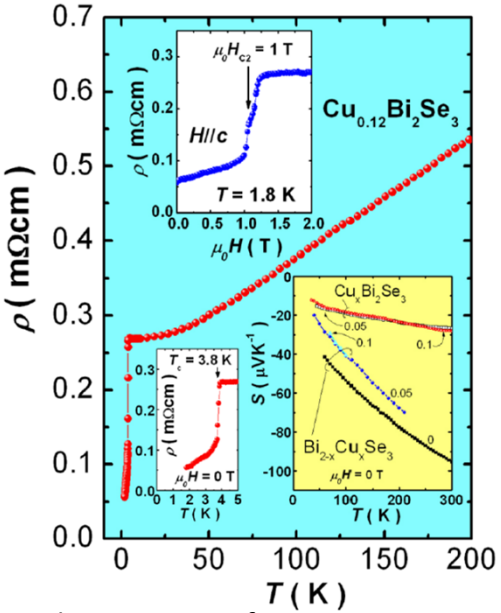

Fig. The resistivity of a $Cu_{0.12}Bi_2Se_3$ crystal with applied current in the ab plane.

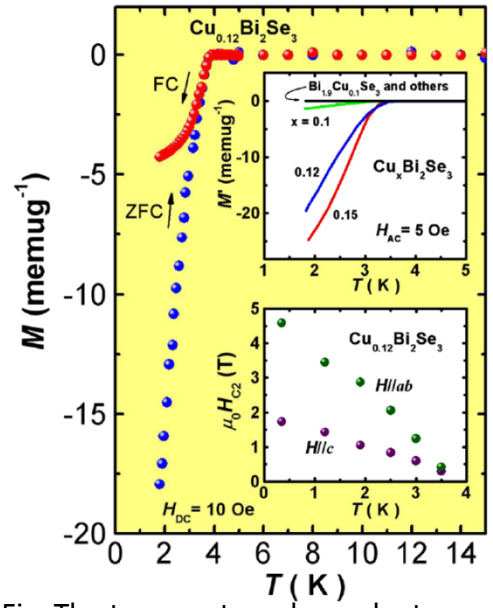

Fig. The temperature dependent magnetization of a single crystal of $Cu_{0.12}Bi_2Se_3$.

Further study: specific-heat measurement

- Moreover, the authors of our paper observed temperature dependent specific-heat, which jumped at the superconducting transition.

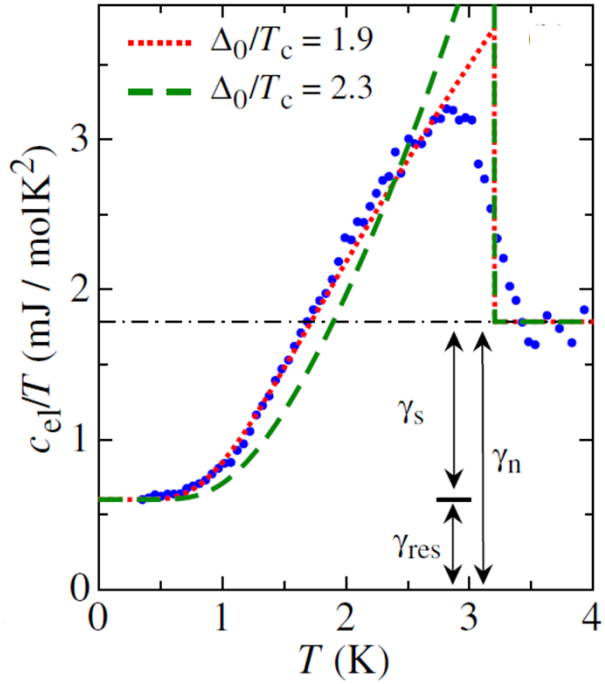

Fig. Measurement of electronic specific heat $C_{el}(T)/T$.

- It suggests a fully gapped and strong-coupling superconducting states, which qualify this system as a candidate for a topological superconductor [L. Fu & E. Berg, 2010].

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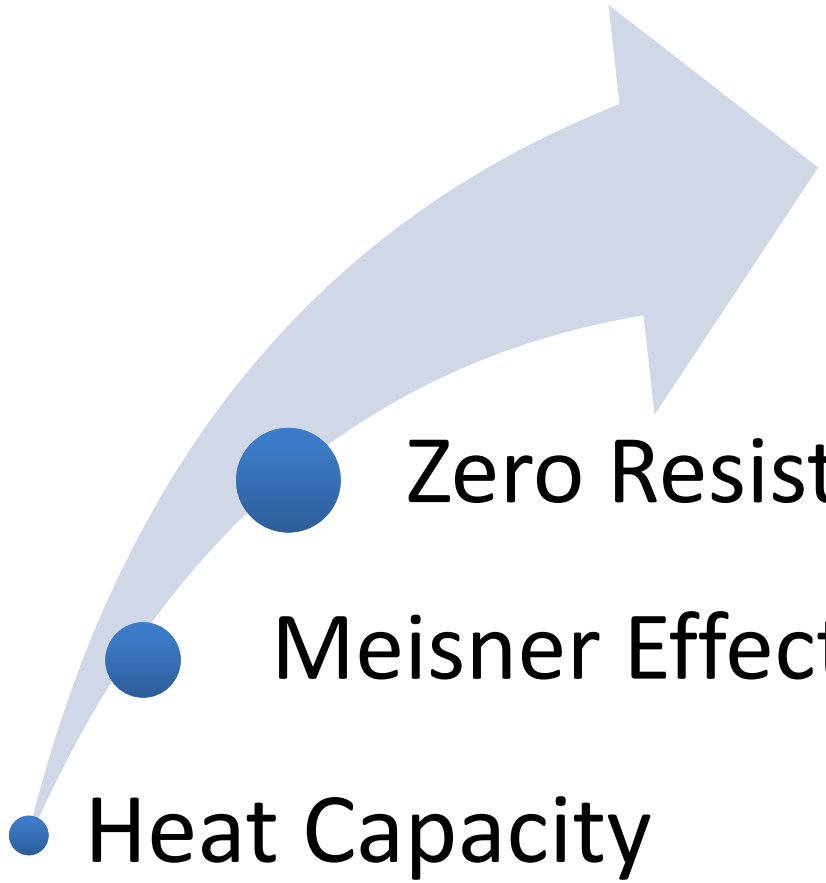
The author's main conclusion



$Cu_xBi_2Se_3$ is a fully gapped, strongly coupling superconductor

Zero Resistivity

Meisner Effect

Heat Capacity

Are they valid conclusions?

- This paper logically concludes that $Cu_xBi_2Se_3$ is superconducting
- Performs further analysis using a general BCS frame work.

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Paper Critique - Scientific Validity

The paper had no obvious flaws

- the authors used standard synthesis techniques
- the data were analyzed within well tested theoretical frameworks

Paper Critique - Importance

The paper will likely have a moderate impact on future research

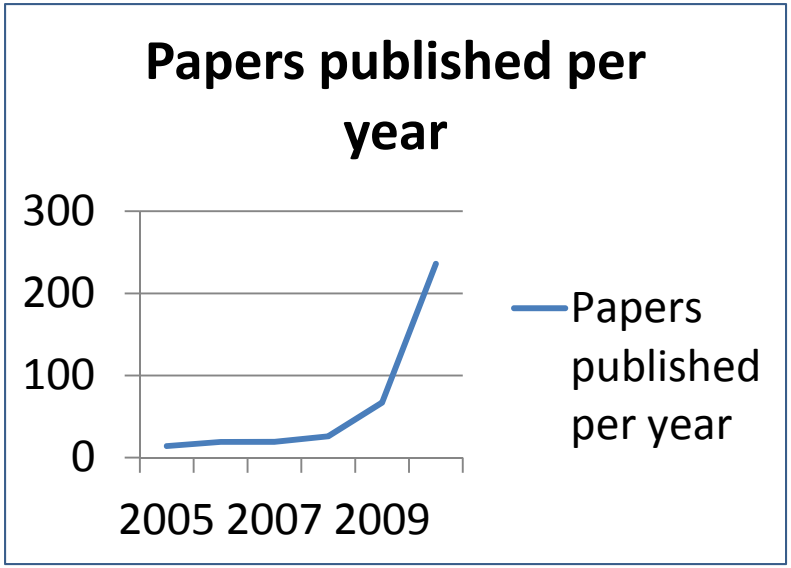
- establishes $Cu_xBi_2Se_3$ as an attractive candidate for further research in topological superconductors

- if $Cu_xBi_2Se_3$ is rejected as a candidate for a topological superconductor interest in the material, and therefore this research, will likely fade

Paper Critique - Interest and Accessibility

Broad Interest

- 'Topological' states are a hot new thing at the moment
- This research has potential applications for quantum computing, esp. for topologically protected coherence



Accessibility

- The paper was well written overall, with good logical flow and clear presentation of results
- One assertion was based on familiarity with BCS theory

Citation Evaluation

Four citations since publication in March 2011

Published in PRL (1), PRL B (3)

3 Experimental papers

- One by same group detailing synthesis techniques
- Two papers reporting other properties of $Cu_xBi_2Se_3$

1 Theory paper

	Document title
1	Bulk superconducting phase with a full energy gap in the doped topological insulator CuxBi2Se3

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	Author(s)	Date	Source title	Citations
	Kriener, M., Segawa, K., Ren, Z., Sasaki, S., Ando, Y.	2011	*Physical Review Letters* 106 (12), art. no. 127004	4

Concluding Remarks

- The paper set out to determine the nature of the superconducting state in $Cu_xBi_2Se_3$
- Through analysis of shielding fraction, specific heat, and resistance data the authors concluded that $Cu_xBi_2Se_3$ is a fully gapped, strongly coupling superconductor

Questions?