Interfaces the Key in Atomically-Thin, 'High Temperature' Superconductors

Zhi Li[1,2]
[1]ARC Centre of Excellence in Future Low-Energy Electronics Technologies
University of Wollongong, NSW, 2522, Australia
[2] Insitutte for Superconducting and Electronic Materials, Australian Institute for Innovative Materials,
University of Wollongong, NSW 2522, Australia

ABSTRACT

An Australian-Chinese collaboration publishing a review of atomically-thin 'high temperature' superconductors has found that each has a common driving mechanism: interfaces.

INTRODUCTION

The team, including researchers from Australia's University of Wollongong and Monash University, and Tsinghua University (Beijing, China), found that interfaces between materials were the key to superconductivity in all systems examined.

The enhancement of superconductivity at interfaces (interface superconductivity enhancement effect) in atomically-thin superconductors is a unique tool for discovering new high-temperature superconductors, and could be used to finally unlock the elusive mechanism behind high-temperature superconductivity.

THE STUDY

Systems studied include:

- elemental metals grown on semiconductors
- single-layer iron-based superconductors
- atomically-thin cuprate (copper based) superconductors

The review investigated the role of molecular-beam epitaxy (MBE), scanning tunnelling spectroscopy (STM/STS), scanning transmission electron microscopy (STEM), physical properties measurement system (PPMS), in fabricating and identifying atomically-thin superconductors.

Interface between elemental metals and semiconductors
High-quality crystalline Pb and In single-layers thin films and double-layer Ga thin films have been fabricated on Si and GaN wafers by MBE, respectively [1,2].

The transition temperature (T_c) of them are expected to be significantly lower than large-scale bulk samples due to fewer electrons at the Fermi surface.

The STM and transport studies show a much higher Tc comparing to expected values. Studies show the interface played an important role in this.

Interface between single-layer FeSe and various insulators
A very high T_c (T_c record in iron-based superconductors) was discovered on the interface between single-layer FeSe and insulators by some of the authors in the review (Fig. 1).

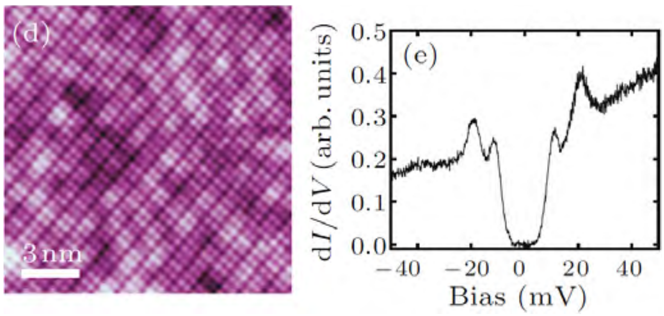


Fig. 1: Superconductivity in single-layer FeSe films grown on STO substrates. Left: STM image, right: scanning tunneling spectroscopy showing superconducting gap with pronounced coherence peaks.

The interface lattice vibration was identified by the authors in the first paper [3]. The experiment has been repeated by many groups world-widely. The importance of interface charge transfer and lattice vibration are confirmed.

Less than single-layer copper based superconductors

Copper based superconductors have a unique sandwiched structure consisting of copper oxide layers, conducting layers and insulating layers.

Studies discovered the copper oxide layer is the superconducting layer and interfaces between different layers play roles of providing electrons and protecting the superconductivity [4].

The authors predict the next breakthrough in superconductors will come soon with novel interfaces as a key factor.

OTHER INFORMATION

The review paper Atomically thin superconductors was published in the journal Small in May 2020 [5].

The properties of novel, atomically-thin materials are studied at the ARC Centre for Future Low-Energy Electronics Technologies (FLEET), a collaboration of over a hundred researchers seeking to develop ultra-low energy electronics to face the challenge of energy use in computation, which already consumes 8% of global electricity [6], and is doubling each decade [7].

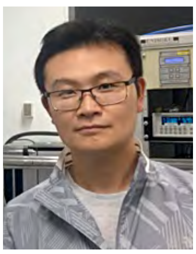
COLLABORATING PERSONNEL

The collaborating personel are Dr Zhi Li (associate investigator), Lina Sang (PhD student, Dr Peng Liu (research fellow), Dr Zengji Yue (research fellow) and Prof Xiaolin Wang (chief investigator) from the Univesrtity of Wollongong, Prof Michael Fuhrer (chief investigator) from Monash University and Prof Qikun Xue (investigator) from Tsinghua University.

Acknowledgement: The authors acknowledge support from the Australian Research Council's support via the Centre of Excellence, Discovery and Future Fellowship programs.

References

[1] T. Zhang et al Nat. Phys. 6. 104 (2010).
[2] H.-M. Zhang et al Phys. Rev. Lett. 114. 107003 (2015).
[3] Q.-Y. Wang et al Chin. Phys. Lett. 29. 037402 (2012).
[4] Y. Zhong et al Sci. Bull. 61. 1239 (2016).
[5] Z. Li et al Small 1904788 (2020).
[6] A.S.G. Andrae, A Total Consumer Power Consumption Forecast Nordic Digital Business Summit, Helsinki (2017).
[7] W. Van Heddeghem Trends in worldwide ICT electricity consumption from 2007 to 2012 (2014).



Zhi Li is an ARC DECRA Fellow at the Institute for Superconducting and Electronic Materials, University of Wollongong, Australia. He is a condensed matter physicist, with a background of topological insulators, interface superconductors and two-dimensional materials. Zhi received his Ph.D. in condensed-matter physics from the Institute of Physics (IOP), Chinese Academy of Sciences (CAS) in 2014. He has expertise in molecular-beam epitaxy (MBE) techniques and scanning tunneling microscopy (STM). Within FLEET (the ARC Centre of Excellence in Future Low-Energy Electronics Technologies) he supports the study of new topological materials by fabricating high quality samples by MBE and investigating them using STM.