PCSI
Room Canyon/Sugarloaf - Session PCSI-MoE
Superconductivity I

Moderator: David Pappas, National Institute of Technology

7:30pm **PCSI-MoE-1 Fluctuating High Temperature Superconductivity in Monolayer FeSe / $SrTiO_3$*, Kyle Shen,* *B Faeth, S Yang, D Schlom,* Cornell University **INVITED**

The nature and origin of the enhanced superconductivity in monolayer FeSe / $SrTiO_3$ has been attracted tremendous interest due to its unique character as an interfacially enhanced high- T superconductor. FeSe / $SrTiO_3$ exhibits a spectroscopic gap opening temperature (T_{gap}) between 60 to 70 K, nearly one order of magnitude higher than that of bulk FeSe (T_c = 8K), and in excess of related electron-doped FeSe-based bulk compounds. This dramatic enhancement remains the largest amongst known superconductors, positioning monolayer FeSe / $SrTiO_3$ as an ideal platform for investigating fundamental questions about interfacial superconductivity. In particular, the combination of its high-T_c and inherently two-dimensional (2D) nature makes FeSe / $SrTiO_3$ suited for exploring the interplay between 2D phase fluctuations and the interfacial enhancement of superconductivity, a better understanding of which could enable the future design and engineering of artificial higher- T_c superconductors. In this work, we employ a combination of *in situ* electrical resistivity and angle-resolved photoemission spectroscopy (ARPES) measurements of monolayer FeSe / $SrTiO_3$ to reveal an unprecedentedly large pseudogap regime between the initial formation of incoherent Cooper pairs (T_{gap} ~ 70K) and the onset of a zero resistance state (T_0 ~ 30 K). Through measurements of the V(I) characteristics, we identify this large pseudogap regime as originating from two-dimensional superconducting fluctuations, establishing the critical role that reduced dimensionality plays in the superconductivity of monolayer FeSe / $SrTiO_3$.

8:10pm **PCSI-MoE-9 Advances and Possibilities of the Materials Innovation Platform with Examples from Spin-ARPES*, Daniel Beaton,*** Scienta Omicron Inc.

The quest for device applications based on quantum materials, such as topological insulators, density wave systems, or superconductors, requires strict control of the environments these materials are exposed to during production and also while under investigation. It is most straightforward to gather all parts of the experiment, from sample growth to state-of-the-art analysis, in one connected UHV system. This approach in creating a so-called Materials Innovation Platform (MIP) has proven to be extraordinarily valuable in recent years.

In this presentation, I will focus on one such configuration; a combination Molecular Beam Epitaxy (MBE) system and Angle Resolved PhotoEmission Spectroscopy with spin detection capability (Spin-ARPES). The advantages of this set-up will be explored, as well as highlighting some of the very recent electronic band structure research performed with such a system. Two specific examples will be reviewed: Yang *et al.*[1] investigation of the impact of photogenerated carriers on the superconducting transition temperature; and advances high efficiency spin-ARPES[2]. The work by Yang *et al.*, enabled by the *in-situ* growth and analysis possibility, shows rapid, reliable, reproducible switching between normal and superconducting states, which demonstrates the possibility of making energy-efficient quantum optoelectronics devices. Future possibilities of Spin-ARPES and laser-ARPES in combination with MIP will also be discussed in relation to how this approach can allow more complete and precise studies of quantum materials.

[1] Yang et al., Nature Communications (2019)10:85, https://doi.org/10.1038/s41467-018-08024-w

[2] Data courtesy: Prof. Dengsung Lin, Dept. of Physics, NTHU, Taiwan

8:15pm **PCSI-MoE-10 Superconductivity at Surfaces Studied by Scanning Tunneling Microscopy*, Yukio Hasegawa,*** The University of Tokyo, Japan **INVITED**

Superconductivity that emerges in metallic surface states is one of the ultimately thin two-dimensional (2D) superconductors. One of the advantages, if compared with other 2D superconductors, is that atomically well-ordered structures can be easily formed in macroscopic dimensions because of the thermal stability through the self-organized structural reconstruction. Basic properties such as atomic structure and electronic states are well characterized by standard surface science techniques including scanning tunneling microscopy (STM), and can be modify in a controlled manner through the deposition and adsorption of additional materials.

One ubiquitous feature of the 2D atomically-thin electronic systems is the natural presence of atomic steps on its substrate. Atomic steps are considered to strongly affect electron transport as they decouple neighboring surface terraces [1]. We have demonstrated that the steps of the √3x√3-In/Si(111) surface superconductor behave as a Josephson junction and hold elongated vortices called Josephson vortices along the steps [2]. On striped incommensurate (SIC) phase of Pb/Si(111) the steps are found to block the propagation of the superconducting proximity effect and enhance it when they are located within the coherence length [3].

In two-dimensional superconductors usual orbital pair breaking of the superconductivity by in-plane magnetic field can be suppressed, allowing the Zeeman pair breaking to determine the critical magnetic field. There is however no protection against perpendicular magnetic fields. Using STM, we found that in narrow terraces of the Pb/Si(111) surface whose width is less than the coherence length superconductivity is protected against perpendicular magnetic fields. It is presumably due to the suppression of orbital pair breaking by the step confinement. Since the density and the coupling strength of the steps can be controlled, our study opens a way to design 2D superconductors that maintain the pair correlation under magnetic field in all directions.

[1] M. Hamada and Y. Hasegawa, Phys. Rev. B 99, 125402 1-5 (2019)

[2] S. Yoshizawa, H. Kim, T. Kawakami, Y. Nagai, T. Nakayama, Xiao Hu, Y. Hasegawa, T. Uchihashi, Phys. Rev. Lett. 113, 247004 1-5 (2014).

[3] H. Kim, S.-Z. Lin, M. J. Graf, Y. Miyata, Y. Nagai, T. Kato, and Y. Hasegawa, Phys. Rev. Lett.,117, 116802 1-5 (2016)

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