

PCSI

Room Ballroom - Session PCSI-MoA1

Superconductivity in Thin Films & Heterostructures

Moderator: Monica Allen, University of California at San Diego

2:00pm **PCSI-MoA1-1 Thin Film Quantum Matter: Unconventional Conventional Superconductivity and More, Joseph Falson**, California Institute of Technology **INVITED**

In this presentation I will discuss recent intermetallic and oxide thin film materials we have grown in our lab, including an array of ultra-thin materials which display magnetic field-induced superconductivity, along with topological materials which are sufficiently clean to show the quantum Hall effect. I will take time to emphasize the correlations between the unique synthesis pathways these compounds take and the physics they display, with the goal of connecting an understanding of subtle physical and chemical distortions with the ability to resolve profound emergent electronic phases.

2:30pm **PCSI-MoA1-7 Stoichiometric FeTe is a Superconductor, Cui-Zu Chang**, The Pennsylvania State University **INVITED**

In this talk, I will first briefly introduce the molecular beam epitaxy (MBE) growth mechanism, and then focus on our recent progress in the MBE growth of FeTe films and heterostructures. FeTe, unlike its superconducting isostructural counterpart FeSe, has long been regarded as an antiferromagnetic (AFM) metal sans superconductivity. Over the past five years, my group has employed MBE to synthesize a series of FeTe-based heterostructures, in which superconductivity consistently emerges. More recently, we developed an approach to grow FeTe thin films followed by post-growth annealing under a Te flux. Using spin-polarized scanning tunneling microscopy and spectroscopy (STM/S), we show that the AFM order in as-grown FeTe films originates from interstitial Fe atoms that disrupt the ideal 1:1 stoichiometry. Remarkably, removing these interstitial Fe atoms via Te annealing produces stoichiometric FeTe films that exhibit no AFM order and instead display robust superconductivity with a critical temperature of ~ 13.5 K. This superconducting state is further confirmed by the observation of Cooper-pair tunneling, zero electrical resistance, and the Meissner effect. Based on these results, we establish a new phase diagram for Fe_{1-x}Te and demonstrate that stoichiometric FeTe is inherently a superconductor, overturning a long-held view that it is an AFM metal [1]. Building on the superconducting stoichiometric FeTe films, we further used MBE to grow a one-quintuple-layer trigonal $(\text{Bi,Sb})_2\text{Te}_3$ layer on top of six-unit-cell tetragonal FeTe. We realized moiré engineering of Cooper-pair density modulation (CPDM) states and demonstrated that CPDM states are a universal phenomenon in moiré superconductors [2].

[1] Yan et al., *Nature* **652**, 342–348 (2026).

[2] Wang et al., *Nature* **652**, 335–341 (2026).

3:00pm **PCSI-MoA1-13 Robust Superconductivity against Al Substitution in LiTi_2O_4 Thin Films, Elijah Robinson, Kashi Panday, Gabe Manzaneres, Prakash Timsina, Sudhan Koirala, Stefan Zollner, Igor Vasiliev, Ludi Miao**, New Mexico State University

The origin of superconductivity in LiTi_2O_4 remains an important question because its mixed-valence Ti network supports a complex electronic state in which carrier filling, disorder, and charge frustration may influence pairing. Building on earlier substitution studies [1], we grow Al-substituted $\text{Li}(\text{Ti}_{1-x}\text{Al}_x)_2\text{O}_4$ thin films on $\text{MgAl}_2\text{O}_4(001)$ by pulsed-laser deposition to test how superconductivity responds when this network is chemically perturbed. Superconductivity persists up to nominal 50% Ti-site substitution even as the normal state becomes substantially more resistive (Fig. 1). This contrast indicates that normal-state conduction and superconductivity have markedly different sensitivities to Al substitution. Zero-resistance transitions and comparatively stable transition temperatures and upper-critical-field scales support the robustness of superconducting transport. The fourfold angular response previously reported in undoped films [2] also survives at the heavily substituted endpoint. Structural characterization reveals lattice contraction, while spectroscopic ellipsometry and density-functional calculations probe the accompanying electronic evolution. The calculations identify stoichiometric LiTiAlO_4 as a carrier-depleted limit, emphasizing that Al substitution changes nominal electron filling and Ti connectivity as well as introducing nonmagnetic disorder. The superconducting response must therefore be understood in the context of a changing electronic system, beyond a simple impurity-scattering picture. Because Al substitution is expected to disrupt the mixed-valence network that can support charge frustration, persistent

superconductivity argues against charge frustration on an intact Ti network being essential to pairing. These films provide a platform for disentangling the roles of carrier filling, disorder, and charge frustration in oxide superconductivity.

[1] P. M. Lambert, P. P. Edwards, and M. R. Harrison, *J. Solid State Chem.* **89**, 345–360 (1990).

[2] H. Xue et al., *ACS Nano* **16**, 19464–19471 (2022).

3:05pm **PCSI-MoA1-14 Characterization of Thin Films for Quantum Information Science, Jesus Marquez**, New Mexico State University

Thin films play a vital role in the development of technologies such as spintronics, low-power-loss electronics, and quantum computing. We characterized thin films to study their unique properties, such as aluminum (Al) and bismuth antimony (BiSb) thin films. BiSb thin films have been characterized using scanning tunneling microscopy (STM); images show nanoscale structures such as triangles, bright interconnected loops, steps, and smooth surfaces, indicating a high-quality film, similar to Bi thin films [1]. Al thin films capped with silicon have been characterized using the physical properties measurement system (PPMS) to measure the critical temperature (T_c) of superconductivity, and results indicate an enhancement of superconductivity compared to the T_c of bulk aluminum, similar to uncapped Al thin films [2]. Properties of BiSb and Al thin films have been obtained using techniques such as STM and PPMS; characterizing thin films is important to study their effects and harness their properties for potential future technologies. This work is supported by NSF DMR 233941 and NSF PREM grant DMR-2423992.

[1] Dong, J. T., Inbar, H. S.; Dempsey, C. P., Engel, A. N., Palmstørn, C. J. Strain Solitons in an Epitaxially Strained van der Waals-like Material. *Nano Lett.* (2024) **24** (15): 4493–4497.

[2] van Weerdenburg, W. M. J.; Kamlapure, A.; Fyhn, E. H.; Huang, X.; van Mullekom, N. P. E.; Steinbrecher, M.; Krogstrup, P.; Linder, J.; Khajetoorians, A. A. Extreme enhancement of superconductivity in epitaxial aluminum near the monolayer limit. *Science Advances*. (2023)

3:10pm **PCSI-MoA1-15 Interplay of Ferromagnetism and Superconductivity in Fe-Doped Ferromagnetic Semiconductors, Anh Le Duc, Hirotaka Hara**, The university of Tokyo, Japan; **Masaaki Tanaka**, The University of Tokyo, Japan **INVITED**

The interplay between superconductivity and ferromagnetism gives rise to unconventional phenomena, including Josephson π -junctions, spin-triplet pairing, and superconducting diode effects, and offers opportunities for exploring Majorana physics. Fe-doped narrow-gap III–V ferromagnetic semiconductors (FMSs) provide a distinctive platform for investigating this interplay by combining ferromagnetic exchange coupling with semiconductor functionality and electrical tunability. Unlike conventional ferromagnetic Josephson junctions, their carrier density and magnetic interactions can be controlled through electrostatic modulation. Our earlier Nb/(In,Fe)As Josephson junctions exhibited long-range proximity-induced superconductivity and unusual magnetic interference patterns, providing evidence for spin-triplet electron pairing [1].

Here, we present two recent advances in epitaxial superconductor/FMS heterostructures grown in situ by molecular beam epitaxy. First, Al films deposited directly on strained (In,Fe)As exhibit superconductivity below 1.1–1.4 K [2]. The dominant Al growth orientation changes from (110) to (111) with increasing the in-plane lattice constant of (In,Fe)As, while superconducting properties correlate with Al morphology and grain size. An anomalous decrease in the critical magnetic field below 0.5 K suggests possible magnetic coupling across the Al/(In,Fe)As interface.

Second, Al/InAs/(Ga,Fe)Sb heterostructures integrate superconducting and magnetic proximity effects in an InAs channel with atomically sharp interfaces [3]. Electrostatic gating can modulate the carrier density in InAs and its wavefunction overlap with the adjacent FMS(Ga,Fe)Sb, offering a route to controlling both Josephson coupling and magnetic proximity interactions. The fabricated junctions exhibit gate-tunable supercurrents and multiple Andreev reflections up to sixth order. Hysteretic and asymmetric Fraunhofer interference patterns provide evidence of induced ferromagnetism and broken time-reversal symmetry. Nonreciprocal critical currents demonstrate a superconducting diode effect with efficiency reaching 20%, while interference analysis suggests enhanced supercurrent near the channel edges. These results establish a promising platform for electrically tunable superconducting spintronics and motivate further exploration of unconventional pairing, topological superconductivity, and Majorana modes.

Monday Afternoon, January 18, 2027

[1] T. Nakamura, L. D. Anh, Y. Hashimoto, S. Ohya, M. Tanaka, and S. Katsumoto, Phys. Rev. Lett. 122, 107001 (2019).

[2] H. Hara et al., APL Materials (2026, in press); arXiv:2609.04744.

[3] H. Hara, L. Baker et al., Communications Materials (2026, in press); arXiv:2603.17101.

Author Index

Bold page numbers indicate presenter

— C —

Chang, Cui-Zu: PCSI-MoA1-7, **1**

— F —

Falson, Joseph: PCSI-MoA1-1, **1**

— H —

Hara, Hirotaka: PCSI-MoA1-15, **1**

— K —

Koirala, Sudhan: PCSI-MoA1-13, **1**

— L —

Le Duc, Anh: PCSI-MoA1-15, **1**

— M —

Manzanares, Gabe: PCSI-MoA1-13, **1**

Marquez, Jesus: PCSI-MoA1-14, **1**

Miao, Ludi: PCSI-MoA1-13, **1**

— P —

Panday, Kashi: PCSI-MoA1-13, **1**

— R —

Robinson, Elijah: PCSI-MoA1-13, **1**

— T —

Tanaka, Masaaki: PCSI-MoA1-15, **1**

Timsina, Prakash: PCSI-MoA1-13, **1**

— V —

Vasiliev, Igor: PCSI-MoA1-13, **1**

— Z —

Zollner, Stefan: PCSI-MoA1-13, **1**