Unlocking Quantum Materials: Prof. Hung-Chung Hsueh Collaborates with Taiwanese Team to Publish in International Journal

Campus focus

Professor Hung-Chung Hsueh, who also serves as the Dean of Research and Development, led a cross-university research team, including third-year doctoral student Chih-En Hsu from our university, to achieve another milestone in the field of quantum materials science. Their latest research paper, "The growing charge-density-wave order in CuTe lightens and speeds up electrons," was published in the prestigious international journal, Nature Communications. Hsueh is the sole corresponding author for the theoretical component. According to the latest data released by Clarivate, the journal has a five-year impact factor of 16.1, highlighting its significant influence on the academic community.

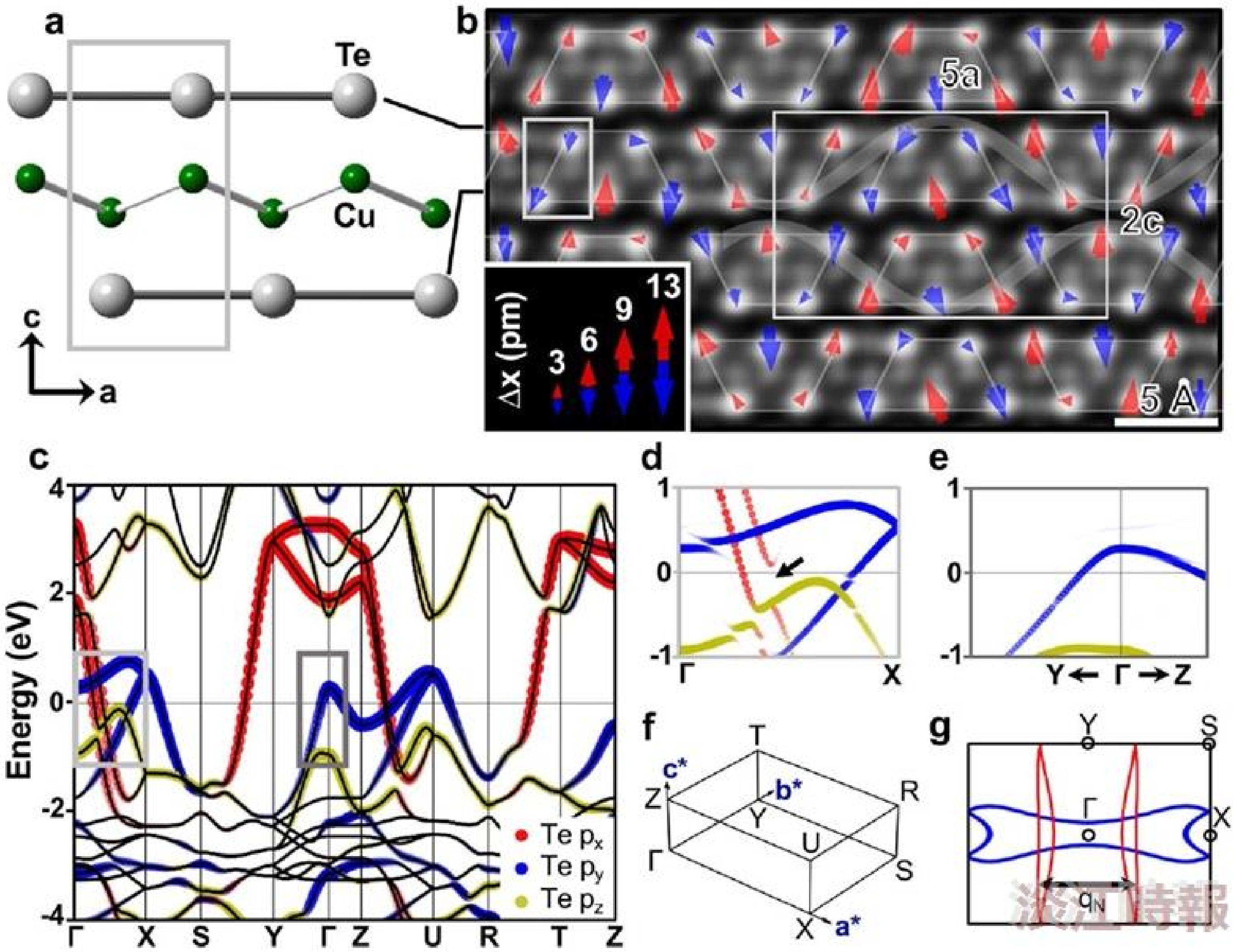
Notably, this paper marks the team's 3rd publication in leading international journals this year, following their previous work published in Nature Communications last April and in the Q1 SCI journal ACS Materials Letters in June 2024. These achievements continue to showcase groundbreaking research at the forefront of materials science.

Prof. Hsueh explained that the collaboration originated from the National Science and Technology Council’s "Taiwan Consortium of Emergent Crystalline Materials" (TCECM) initiative, which brings together local scientists to create a uniquely Taiwanese advanced materials research platform. Hsueh’s theoretical team closely collaborated with the crystal growth team led by Professor Chin-Shan Lue, Distinguished Professor of the Department of Physics and Director of the Key Materials Program at the Academy of Innovative Semiconductor and Sustainable Manufacturing at National Cheng Kung University, as well as Professor Ming-Wen Chu’s experimental team at National Taiwan University’s Center for Condensed Matter Sciences. Their joint efforts across theoretical modeling, experimental verification, and material preparation have led to multiple breakthroughs in quantum materials research.

Using many-body perturbation theory in condensed matter physics, the team conducted first-principles calculations on electronic structures and energy spectra to validate the novel physical phenomena observed in experiments. The study focused on high-quality CuTe crystals with charge density wave (CDW) characteristics. These crystals, grown by Prof. Lue's team, exhibit ordered properties of fluctuating charge density waves, which significantly alter electronic properties in quantum materials. The team aims to address core scientific questions and explore potential applications through continued collaboration. Hsueh noted that this research has garnered significant attention from Japan's academic community in quantum materials.

The study also benefited from a high-resolution momentum-resolved spectroscopic setup established by NTU's team, which allowed experimental observation of the subtle interactions between static charge density waves and dynamic plasmon oscillations in CuTe crystals. This setup provided critical validation for Hsu's theoretical predictions, strengthening the theoretical framework with meticulous experimental support. Hsueh remarked, "Our findings demonstrate the exceptional achievements of Taiwan's materials science community in theoretical and experimental innovation. Despite limited resources, the close interdisciplinary collaboration of the research team has led to recognition by internationally influential top-tier journals, proving that Taiwan can contribute groundbreaking insights to cutting-edge materials science."

Chih-En Hsu is currently furthering his studies at the University of Southern California. Hsueh shared that Hsu is a talented young scholar with multiple ongoing research projects and expressed his enthusiasm for sharing new technologies with emerging researchers. Moving forward, Hsueh plans to deepen collaboration with top domestic and international teams to expand influence in the latest global materials research, laying a stronger foundation for Taiwan's presence in the global academic arena.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The growing charge-density-wave order in CuTe lightens and speeds up electrons

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Charge density waves (CDWs) are pervasive orders in solids that usually enhance the effective mass (m*) and reduce the Fermi velocity (υ_F) of carriers. Here, we report on the inverse – a reduced m* and an enhanced υ_F correlated with the growth of the CDW order in CuTe with gapped, practically linearly dispersing bands – reminiscent of emergent CDW-gapped topological semimetals. Using momentum-dependent electron energy-loss spectroscopy (q-EELS), we simultaneously capture m* and υ_F of the CDW-related, practically linearly dispersing electrons by plasmon dispersions across the transition (335 K, T_{CDW}), with m* of 0.28 m_0 (m_0, the electron rest mass) and υ_F of ~ 0.005*c* (*c*, the speed of light) at 300 K. With the growth of the CDW order-parameter strength toward 100 K, the electrons become lighter and move faster by ~ 20%. Thorough inspection below T_{CDW} unveils the essential role of the increasing opening of the CDW gap. CuTe is a rich platform for the exploration of CDW/correlation physics with q-EELS established as a useful probe for this type of physics.


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