

Physics Faculty and Students Achieve Breakthrough Surge in Research Output, with Publications in Leading International Journals

Campus focus

The Department of Physics has recently continued to demonstrate strong research capabilities. Faculty members and students, in collaboration with leading international teams, have achieved significant breakthroughs in materials science, quantum physics, and high-performance computing. Their research results have been published in prestigious international journals, with some featured on journal covers, and have also been shortlisted for the ACM Gordon Bell Prize, often regarded as the “Nobel Prize of supercomputing.”

Lithium Battery Breakthrough: Hsiao-Tsu Wang Team Unveils High-Voltage Stability Mechanism

Amid the rapid expansion of green energy transition and the electric vehicle industry, improving battery energy density and lifespan has become a central focus of global scientific research. Associate Professor Hsiao-Tsu Wang from the Department of Physics led first-year graduate students Yi-Hong Chang and Chi-Feng Lee, in collaboration with Distinguished Chair Professor Way-Faung Pong, to conduct an in-depth study on lithium-rich manganese-based (LMR) cathode materials. The research was published in the prestigious international journal *ACS Applied Materials & Interfaces* (impact factor 8.2) and was selected as a cover article.

Although LMR materials are considered promising for enhancing energy density, they have long faced challenges such as oxygen release and structural degradation under high-voltage operation. The key breakthrough of Wang's team lies in utilizing the Scanning Transmission X-ray Microscopy (STXM, TPS 27A1) beamline, jointly established by Tamkang

University and the National Synchrotron Radiation Research Center (NSRRC). With nanoscale spatial resolution, the team was able, for the first time, to directly observe subtle differences in the electronic structure between the particle surface and interior.

Wang explained that the study identified a “ π -type superexchange” spin-exchange mechanism formed in surface-modified materials. This mechanism establishes a more stable electronic coupling pathway, effectively suppressing unstable reactions during redox processes and significantly enhancing high-voltage stability.

The critical STXM data and conclusions of this study were all generated at TPS 27A1. Wang expressed gratitude for Tamkang’ s strong research environment and gave special thanks to Way-Faung Pong for his contributions to the beamline's construction and technical guidance, as well as to Assistant Researcher Hung-Wei Shiu from NSRRC, also an alumnus of the Department of Physics, for his efforts in both construction and experimentation. This Taiwan - U.S. collaborative research successfully connected the battery R&D division of General Motors with the Department of Materials Science & Engineering at the University of Michigan, integrating industrial application needs with fundamental electronic structure analysis. Spanning material design, electrochemical testing, and advanced nanoscale synchrotron studies, the project established a comprehensive international research framework. It provided critical parameters for the design of next-generation high-energy-density batteries.

Participating students Yi-Hong Chang and Chi-Feng Lee noted that although the research process was complex and required countless rounds of validation, seeing their work featured on the cover of an international journal brought immense satisfaction and further strengthened their commitment to pursuing research careers.

New Frontiers in Quantum Materials: Hung-Chung Hsueh, Chih-En Hsu Lead Theoretical Innovation

In the fields of quantum materials and low-dimensional electronic systems, Professor Hung-Chung Hsueh and alumnus and postdoctoral researcher Chih-En Hsu have collaborated with international teams to produce a series of significant research breakthroughs. Working with the University of Southern California (USC) and National Taiwan University, they published two major studies on novel physical mechanisms involving Wigner crystal excitons and atomic-scale MoS₂ plasmons.

First, in collaboration with Professor Zhenglu Li of USC, they published their work in the Proceedings of the National Academy of Sciences (impact factor 10.6), revealing the formation mechanism of generalized Wigner-crystal excitons in moiré heterostructure systems. Using advanced first-principles GW many-body perturbation theory calculations, the study accurately captured the crystallized states of electron-hole pairs under strong Coulomb interactions. It demonstrated that, through modulation of superlattice potentials, excitonic states can remain stable at room temperature and exhibit excellent optoelectronic properties, opening new pathways for optoelectronic sensors and tunable quantum materials.

Subsequently, together with recent graduate Yung-Ning Hsu and the experimental team led by Director Ming-Wen Chu of NTU's Center for Condensed Matter Sciences, they published another study in Physical Review Research (impact factor 4.4). This work revealed that monolayer atomic-scale MoS₂ exhibits ultrafast long-wavelength plasmon propagation, deepening understanding of plasmon physics in low-dimensional materials and offering strong potential for the development of high-speed terahertz detectors and nanophotonic devices.

Beyond theoretical innovation, Hsu has also made history in the field of high-performance computing (HPC). As a key member of the BerkeleyGW team, he contributed to achieving a breakthrough computing performance of 1.069

ExaFLOP/s on the Frontier supercomputer at Oak Ridge National Laboratory and the Aurora supercomputer at Argonne National Laboratory.

Professor Hsueh noted that the research simulated electron-phonon coupling many-body problems involving more than 17,000 atoms and was shortlisted for the prestigious ACM Gordon Bell Prize. Hsu is the first Taiwanese scholar ever to be shortlisted for this award. This achievement not only demonstrates the international competitiveness of Tamkang University's physics research in supercomputing simulations but also provides strong momentum for future studies in superconductors and strongly correlated systems.

Breakthrough in Nanomaterial Band Structure: Chi-Cheng Lee Publishes in Nano Letters

Associate Professor Chi-Cheng Lee of the Department of Physics collaborated with Assistant Professor Naoya Yamaguchi and Professor Fumiyuki Ishii of Kanazawa University, as well as Professor Taisuke Ozaki of the University of Tokyo, to publish a joint study in the leading international journal Nano Letters (impact factor 9.9). The team proposed a new method called "Giant Molecule Band Unfolding," which enables the reconstruction of band structures in nanomaterials.

The study reveals that the electronic structure of nanomaterials exhibits "band-like" characteristics similar to infinitely extended systems—akin to the quantum-scale amplification seen in the film Ant-Man. According to Lee, the concept behind this research, described as "a decade in the making", dates back more than ten years. Beginning with the design of basis functions and progressing through software development, he and Naoya Yamaguchi advanced the work over a long period before successfully establishing this new method.





