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Exploiting atomically thin materials for energy efficient electronics

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Energy-inefficient devices consume more power, leading to higher greenhouse gas emissions and increased electricity costs, making it imperative to improve energy efficiency for reducing the global carbon footprint, conserving resources and promoting sustainable development in our increasingly digital world.

The steady improvement in the performance and versatility of electronic systems is largely due to the scaling down of transistors and their derivatives, allowing for smaller, more powerful and versatile electronics. By shrinking, stacking and densely packing components, engineers have added functionality without expanding the systems' footprints. However, these advancements have introduced challenges, particularly in power dissipation, which directly impacts energy efficiency. As a result, electronics engineers, material scientists and physicists worldwide are striving to address the degradation in energy efficiency of electronics caused by the continuous miniaturization and denser arrangements.

Among those people is Arnab Pal, a recent UC Santa Barbara doctoral graduate in electrical and computer engineering. His doctoral research was recognized with a

prestigious Ph.D. Student Fellowship from the Institute of Electrical and Electronics Engineer (IEEE) Electron Devices Society (EDS), annually awarded to a single Ph.D. student from the entire Americas and to a total of three Ph.D. students worldwide.

“The IEEE EDS Ph.D. Student Fellowship is one of the most prestigious awards for doctoral students working in the broad arena of physical electronics,” said UC Santa Barbara electrical and computer engineering professor Kaustav Banerjee, who is Pal’s advisor. “Arnab’s achievements in his research are certainly most deserving of this honor.”

A leader in the field of nanoelectronics, Banerjee is internationally recognized for his pioneering work on energy-efficient electronics using 3D integrated circuits and for overcoming fundamental miniaturization challenges in microelectronics exploiting “atomically-thin” two-dimensional (2D) materials.

Pal joined Banerjee’s Nanoelectronics Research Lab (NRL) in 2016 to pursue his Ph.D. His doctoral research centered on exploring the fundamental properties of 2D materials in improving the energy efficiency and performance of next-generation information processing and storage electronic devices.

“I am deeply honored to receive this prestigious award from the IEEE Electron Devices Society, which recognizes the technological innovations of young Ph.D. researchers,” Pal said. “As the only student from the Americas and the fourth from the NRL and UC Santa Barbara to earn this distinction, I am particularly grateful to my advisor, Professor Kaustav Banerjee. His unwavering support, invaluable insights and inspirational guidance have been instrumental in shaping my research journey. His mentorship not only fueled my passion for discovery but also empowered me to achieve the results that made this recognition possible.”

The IEEE Electron Devices Society Ph.D. Student Fellowship Award recognizes a demonstrated ability to perform independent research in the field of electron devices and a proven history of academic excellence. Pal recently completed his Ph.D. in electrical and computer engineering, where his research focused on exploring the fundamental physics of 2D materials in designing high-performance transistors and neuromorphic electronics with brain-like energy-efficiency.

Among Pal’s other early-career accomplishments are receipt of the UCSB Graduate Division Dissertation award (2023), the Outstanding TA Award from UCSB’s ECE Department (2018, 2019), and the Academic Excellence Award for his top of the

class performance at IIT-Kanpur (2015) during his masters degree. His research contributions have appeared in prestigious international journals, including Nature Communications, Advanced Materials,and IEEE Transactions on Electron Devices, as well as the premier device technology conference – the IEEE International Electron Devices Meeting (IEDM), where he co-authored nine papers. His IEDM 2022 work on designing optimal metal-2D semiconductor contacts was also highlighted by Intel, underscoring its relevance to the mainstream microelectronics industry.

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