THE CHINESE UNIVERSITY OF HONG KONG
Centre for Advanced Research in Photonics &
Department of Electronic Engineering
Seminar

Phase-change memory materials in electronics and photonics

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Abstract

The global demand for data storage and processing has increased exponentially in recent decades. Non-volatile memory technologies combine the advantages of persistent storage and fast operation speed, which largely optimize the memory hierarchy for better computing and power efficiencies. Chalcogenide phase-change materials (PCMs) are leading candidates for non-volatile memory devices. PCMs were initially released to the market as rewritable optical disks in the 1990s and became popular as electronic devices since 2000. Currently, high-density PCM-based products, such as Intel Optane memory, are available in the global memory market, known as persistent memory (PMem). Thanks to the rapid development of silicon photonics, the integration of PCMs with silicon waveguides opens up the possibility of on-chip photonic phase-change memory applications. PCM exploits the large contrast in electrical resistance or optical reflectance/transmittance between its amorphous state (logic state = 0) and crystalline state (logical state = 1) to encode digital information. The fast and reversible phase transition at elevated temperatures and yet good thermal stability of the two states at room temperature guarantees both high operation speed and long-term data storage. Moreover, the contrast window of PCM is also wide enough to accommodate many more intermediate states for analog computing. It is feasible to emulate the synaptic learning rule or neuronal dynamics that mimic biological systems using a single electronic or photonic memory cell, supporting the development of neuromorphic in-memory computing. In this talk, I will discuss the microscopic mechanisms of the rapid crystallization dynamics, optical contrast, resistance drift, power consumption and cycling endurance of PCM. I will highlight the essential role of materials design and engineering in improving the performance of PCM-based memory and neuromorphic computing. I will also discuss how to combine the advantages of *ab initio* simulations with machine-learned molecular dynamics simulations and coarse-grained device simulations via the finite-difference time-domain method to promote the design and optimization of phase-change device structures for non-volatile electronics and photonics. At last, I will outline the remaining challenges and opportunities lie ahead for the field.

Biography

Wei Zhang is a Changjiang Scholar, a professor of materials science and the director of Center for Alloy Innovation and Design (CAID) at Xi'an Jiaotong University, China. He received his bachelor and master degrees both at Zhejiang University, China, and his Ph.D. degree with distinction (Summa Cum Laude) at RWTH Aachen University, Germany. After a short postdoc at RWTH, he joined XJTU in 2015. His research interests include phase-change materials for non-volatile memory and neuro-inspired computing, first-principles materials design, machine-learning methods for amorphous materials. Prof. Zhang has published 90 peer-reviewed articles in high-profile journals, including Science (3), Nature Materials (3), Nature Electronics (2), Nature Review Materials and so on. He serves as a committee member for the European Phase-Change and Ovonic Symposium (E\PCOS) and the coordinator for Sino-German bilateral symposium on electronic and memory materials.

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