Stephen R. Elliott

Title: *Chalcogenide phase-change materials: past and future*

Abstract: Phase-change (PC), non-volatile memory (NVM) materials, such as Ge2Sb2Te5 (GST), encode stored digital binary data as structural changes in the material. Reversible, ultrafast (ns) transformations between metastable semiconducting/non-reflective amorphous and near-metallic/reflective crystalline states occur as a result of Joule heating, caused by applied voltage/laser write pulses, in electronic/optical NVMs, respectively. The canonical PCM, GST, was originally discovered and developed for optical NVM; although it also works as an electronic NVM (phase-change random-access memory, PCRAM) material, nevertheless it is not optimal in this role. In this talk, I will discuss the effects of 'doping' (or chemical modification) of GST, with elements such as nitrogen or first-row transition metals, in order to improve PC characteristics, such as crystal grain size, and optical-reflectivity contrast for optical NVM, and to introduce additional PC functionality, e.g. magnetism for electronic NVM, respectively. These studies have been carried out by *ab initio* molecular-dynamics (AIMD) simulations, in which new compositions of doped PCMs have been obtained by a process of *in silico* materials discovery. I will also describe a strategy to increase the rate-limiting crystallization speed of PCMs, which does not also decrease long-term data retention in the amorphous state (i.e. deleterious spontaneous crystallization), by means of the use of 'priming' pre-pulses. AIMD simulations indicate the structural-ordering origin of this priming behaviour. In this way, we have reduced the crystallization time of GST to ~500ps, well below the critical switching time of ~1ns needed to replace volatile Si-based CMOS DRAM by an NVM-equivalent 'universal memory'. Finally, I will outline very recent work which demonstrates that GST PCM cells can also be used to perform Boolean logic operations, thereby combining memory and processing operations in the *same* cell.

Biography: Stephen Elliott is Professor of Chemical Physics in the Department of Chemistry at Cambridge University and a Fellow of Trinity College, Cambridge, UK. He has published more than 340 papers in several fundamental areas of glass science such as structure and modeling of amorphous solids, vibrational states of disordered solids, electronic structure of glasses, amorphous chalcogenides, and phase-change materials. He is the author or coauthor of three widely used textbooks ("Physics of Amorphous Materials"; "The Physics and Chemistry of Solids"; and "Optical Non-linearities in Chalcogenide Glasses and their Applications" (with A. Zakery)) - the first one is considered a must-read for all young scientists working in the fundamental aspects of amorphous materials.

Prof. Elliott received his PhD from Cambridge University, UK, working in the Physics and Chemistry of Solids group at the Cavendish Laboratory under the guidance of Professors E.A. Davis and N.F. Mott (a 1977 Nobel Prize in Physics). Prof. Elliott received the prestigious Zachariasen Prize in 1992 given to the researcher aged under 40 who has made the most significant and innovative advances in the field of non-crystalline materials. In 2001, Prof. Elliott became the very first recipient of the Stanford R. Ovshinsky Award for excellence in non-crystalline chalcogenides. He is or has been an editor or a coeditor or a member of advisory editorial boards of a number of prestigious journals, such as Philosophical Magazine, Philosophical Magazine Letters, Journal of Non-crystalline Solids, Journal of Optoelectronics and Advanced Materials, and European Journal of Pure and Applied Physics.

Prof. Elliott has devoted much of his recent work to the understanding of photo-induced effects in amorphous chalcogenides and of chalcogenide Phase-Change Materials (PCMs), which are already used in the manufacture of rewritable optical discs and flash memory in Nokia Asha smartphones. His current research continues in the field of PCMs, examining the microscopic origins of the fast amorphous –crystalline phase transitions, and the design of new PCMs for in-memory logic and neuromorphic computing.