

Phase-change Nanoparticles for Optical Switching and Memory

Structural phase transitions are occurring all around us in the natural world, for example on the very large scale in the form of melting polar ice caps. On a more familiar scale, similar changes form the basis of today's CD, DVD and Blu-Ray recording technologies. The Nanophotonics Group at the University of Southampton's Optoelectronics Research Centre has shown that phase changes initiated by optical or electron-beam excitation may be exploited on the ultra-small, nanometre scale to enable new high-capacity optical technologies for future data processing and storage applications [1].

With increasing temperature or strength of applied external excitation, phase transitions in nanoparticles (Fig. 1) proceed through a dynamic coexistence of forms over an extended temperature range: the high energy phase (B) appears first on the surface of the particle and gradually consumes the core. For as long as both phases remain present, the transition is fully reversible (reducing the temperature or removing the excitation will restore the particle to its original state) but once complete, the particle becomes stable in the new phase and will remain there until substantially cooled.

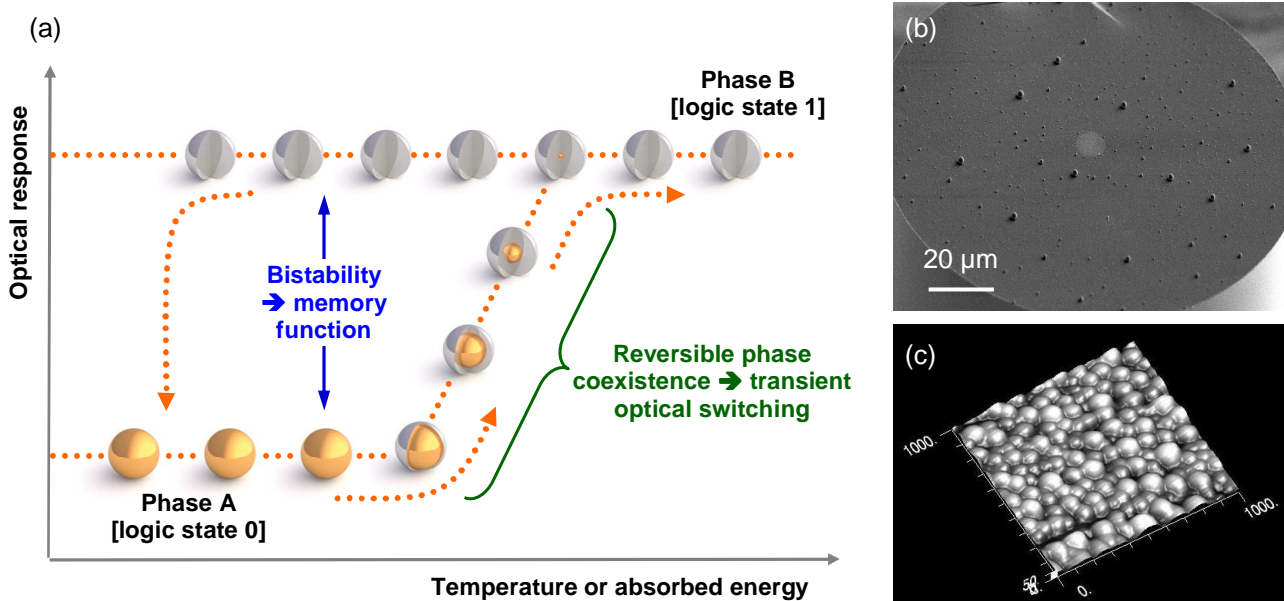


Fig. 1: (a) Phase change optical functionality in a nanoparticle: Optical properties (reflectivity, transmission, cathodoluminescent emission, etc.) are functions of phase composition. The nature of the transition cycle provides for both transient and bistable switching. (b) Scanning electron microscope image of an optical fibre tip on which gallium nanoparticles have been grown. (c) Atomic force microscope image of gallium nanoparticles formed in the central core area of a fibre tip as shown in (b).

In certain materials, such as gallium, a phase transition can bring about dramatic changes in the optical properties of the particle, enabling transient all-optical switching and signal modulation in the phase-coexistence range [2,3] and optical- or electron-beam addressed memory function for data storage in the bistable mid-section of the transition loop [4,5]. These functionalities are achieved in extremely small volumes of material (particle diameters ~ 50 nm) using very low (picojoule) switching energies.

References

- [1] N. I. Zheludev, *Nat. Photon.* **1**, 551 (2007).
- [2] V. A. Fedotov, K. F. MacDonald, and N. I. Zheludev, *J. Opt. A: Pure Appl. Opt.* **7**, S241 (2005).
- [3] B. F. Soares, K. F. MacDonald, V. A. Fedotov, and N. I. Zheludev, *Nano Lett.* **5**, 2104 (2005).
- [4] B. F. Soares, F. Jonsson, and N. I. Zheludev, *Phys. Rev. Lett.* **98**, 153905 (2007).
- [5] A. I. Denisyuk, K. F. MacDonald, N. I. Zheludev, and F. J. García de Abajo, *Jpn. J. Appl. Phys.* (in press).