Nanoscale engineering could lead to faster, smaller, more stable electronic memories

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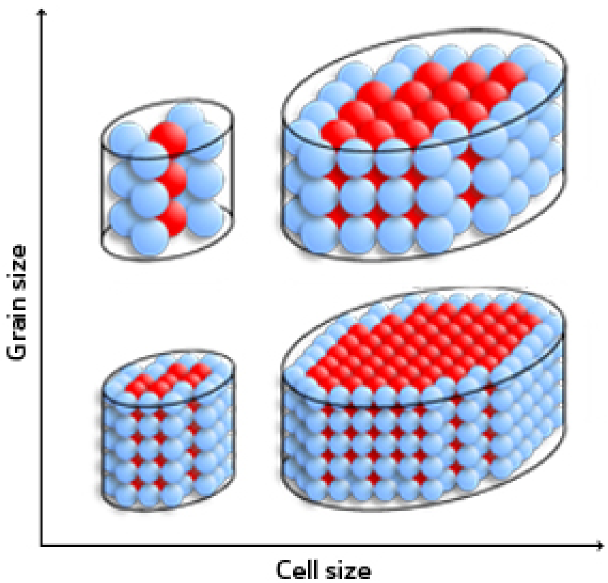

Phase change in NGST is faster when the grains are smaller and arranged into tinier cells, owing to an increase in the ratio of surface (blue) to internal (red) grains and the interface between grains. © 2012 Nature Publishing Group

Developing a so-called 'universal memory', or the perfect electronic memory, has long been the holy grail of electronic engineering. A universal memory should have a fast read and write speed, high reliability, low power consumption, and be compatible with other electronic components as well as non-volatile; that is, it should retain the data even when the device's power is switched off.

Weijie Wang at the A*STAR Data Storage Institute, Singapore, and her co-workers have now shown that nanometer-scale engineering of so-called phase-change materials could lead to just such a device. The atoms in phase-change materials, such as $Ge_2Sb_2Te_5$ (GST), can arrange themselves into one of two configurations. These two 'phases' act as the ones and zeroes in digital information, and a pulse of electricity can change the material from one to the other. The ease with which GST changes phase, however, is both a blessing and a curse. On the plus side, it means that it can store data very quickly; but, on the down side, it is prone to switching phase unexpectedly and thus losing the data.

"We have learnt how to create fast and stable phase-change memory technology that is scalable to nanometer sizes by developing a better understanding of the mechanisms that determine the atomic structure of these materials," says Wang.

Phase-change random-access memory (PCRAM) is one of the most promising approaches to universal memory. Previous research has shown that adding nitrogen to GST, creating NGST, makes a more stable material, but also slows the phase-change process.

Wang and her co-workers showed, however, that both high speed and high stability are possible simultaneously. They experimentally demonstrated that phase change in NGST became much faster by scaling down physically. "We developed a dual-scaling technique to reduce both the overall material volume and the size of the individual grains that make up NGST," she explains.

When the researchers deposited small-grain NGST into the pores of a thin film of silicon dioxide, they found that phase change in 20-nanometer-wide structures containing 5 nanometer grains was as much as 17 times faster than devices created in 200-nanometer pores. This increase in speed is because the mechanism that drives phase change is fundamentally different for smaller grains that are in smaller cells, owing to their higher surface-area-to-volume ratio.

"In principle, this method is applicable to all types of phase-change materials," says Wang. "So, appropriate choice of device structure and phase-change material opens new opportunities for optimizing memory device performance."

More information: Wang, W., Loke, D., Shi, L., Zhao, R., Yang, H. et al. Enabling universal memory by overcoming the contradictory speed and stability nature of phase-change materials. *Scientific Reports* 2, 360 (2012). dx.doi.org/10.1038/srep00360

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