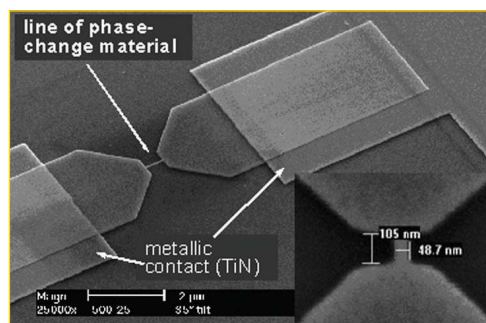


## In line for phase-change memory cell

NANOTECHNOLOGY



Micrograph of a phase-change memory cell. Inset: a cell of length ~100 nm and width ~50 nm.

Philips Research Labs' new 'line-cell' Si chip memory has an ultrathin line of phase-change material. An electric current is used to heat the material to its phase-change temperature, where it switches reversibly between crystalline and amorphous phases, and to detect the change in resistance [Lankhorst *et al.*, *Nat. Mater.* (2005) 4 (4), 347]. In phase-change ovonic unified memory, a high voltage is needed in the high-resistance amorphous state to drive enough current to heat it – impractical for future complementary metal-oxide semiconductor (CMOS) Si chips.

So, Philips developed a doped Sb/Te material that shows threshold switching, where highly conductive filaments form and Joule heating occurs at a low electric field (~14 V/μm for lines shorter than 200 nm). Unlike other nonvolatile memories, performance improves at the nanoscale, since crystallization occurs from the edge of the amorphous volume inwards. As chip sizes shrink, reducing the line length (e.g. to 50 nm) reduces the voltage for threshold switching (to 0.7 V). The Sb/Te line is surrounded by dielectric (SiO<sub>2</sub>), which has low thermal conductivity and dissipates little power and current. This allows smaller cells and faster operation. In test devices, a 30 ns phase change and use of symmetrical pulses makes programming 100-200 times faster than flash memory, making it a feasible replacement for dynamic random access memory (DRAM). Further current reduction is possible by using better thermal insulation material or by shrinking the line's cross section.

Also, device fabrication needs just a few extra lithography steps for integration into CMOS logic processes, suiting low-cost production.

Mark Telford

## Chemical control of magnetic semiconductors

MAGNETIC MATERIALS

Scientists at the University of Washington have provided the first evidence that ferromagnetism in Mn-doped ZnO relies critically on factors other than the magnetic dopants themselves [Kittilstved and Gamelin, *J. Am. Chem. Soc.* (2005), doi:10.1021/ja050723o], and demonstrated the controlled chemical manipulation of high-Curie-temperature ( $T_c$ ) ferromagnetism in a diluted magnetic semiconductor (DMS) [Kittilstved *et al.*, *Phys. Rev. Lett.*, in press]. Targeted chemical perturbations were used to manipulate 300 K magnetic ordering in ZnO DMSs in controllable ways: *p*-type perturbation by amine binding then calcination induced ferromagnetic ordering in Mn<sup>2+</sup>:ZnO but quenched ordering in Co<sup>2+</sup>:ZnO; *n*-type perturbation by Zn interstitial vapor diffusion quenched ferromagnetism in Mn<sup>2+</sup>:ZnO but induced it in Co<sup>2+</sup>:ZnO. This is consistent with theoretical models in which ZnO DMS ferromagnetism is mediated by itinerant carriers. Control over physical properties also enables testing of proposed microscopic mechanisms for long-range magnetic exchange

interactions in oxide DMSs, says Kevin R. Kittilstved. The availability of DMSs with reliable magnetic properties should now focus attention on elucidating their magnetotransport properties. In particular, the electronic structure of Mn<sup>2+</sup>:ZnO is most analogous to those of ferromagnetic DMSs used in prototype spintronic devices (which process information by manipulating electron spins). These currently operate only at cryogenic temperatures.

Implementation requires an understanding of the relationships between compositional, structural, and physical properties. So, future work will probe the identities and properties of lattice defects that can be introduced chemically, and the dependence of magnetic properties on such chemical parameters. The results also suggest new possibilities for the development of hierarchical magnetoelectronic device structures by integrating ferromagnetic oxide nanostructures with organic conducting polymers using soft-chemical methods, says coauthor and lead researcher Daniel R. Gamelin.

Mark Telford

## Molecular spintronics a reality?

MAGNETIC MATERIALS

Theoretical work from Trinity College Dublin, Ireland, along with coworkers in the UK and Spain, has demonstrated the potential for highly tunable, self-assembling molecular spintronics. This chemical approach toward spintronics may have great potential for the multibillion-dollar industry of magnetostorage devices. [Rocha *et al.*, *Nat. Mater.* (2005) 4 (4), 335]. Spintronic devices use the spin of an electron as well as its charge. The team, led by Stefano Sanvito, shows that organic spin valves can achieve high magnetoresistance values and so could overcome previous efficiency and performance pitfalls of spintronic devices using conventional inorganic materials.

"We demonstrate that it is possible to inject spins into a molecule with very high efficiency," says Sanvito. "The lack of hyperfine and spin-orbit interactions in organic molecules means spin coherence can be maintained over longer times and distances than conventional metals and semiconductors," he explains.

The group show that an organic molecule sandwiched between Ni contacts can display magnetoresistance ratios of up to 600%. The effect can be tuned by engineering the side and end groups of the molecules.

The team used a combination of density functional theory and a nonequilibrium Green's function method to obtain current-voltage characteristics of the spin values. The algorithm is incorporated in a code created to compute magnetotransport properties at the atomic level. The 'SMEAGOL' code is freely available at [www.smeagol.tcd.ie](http://www.smeagol.tcd.ie).

Patrick Cain