Diode-Free Architecture Promises Dramatic Increase in Memory Density in Magnetic Random Access Memory Devices

Magnetic random access memories (MRAMs) utilize the orientation of magnetization of a thin ferromagnetic film to store digital information in a nonvolatile manner. Currently, this requires the coupling of a diode (the selective component) in series with a magnetic tunnel junction (MTJ, the storage node). Unfortunately, the surface area of the typical diode used in such an array is at least 10^3 μm^2, versus approximately 0.17 μm^2 for the smallest MTJ. The diode is thus the limiting factor in determining the storage density of an MRAM device.

In the September 25 issue of *Applied Physics Letters*, Frank Z. Wang of the School of Informatics and Multimedia Technology at the University of North London reported the development of a diode-free MRAM architecture. Since the absence of diodes means that all junctions of the MTJ array share a mutual electrical connection, it would seem to be impossible to read the status of any given MTJ without including the contributions from the rest of them in the array. Wang solved this problem by introducing a "virtual ground,"a concept used in operational amplifiers, into a 2 × 2 bit memory "chiplet." Because the input impedance of an operational amplifier is very high or infinite, no current can flow into or out of the inverting input terminals, creating a virtual ground at 0 V. MTJs were fabricated as a sandwich by deposition of a 100 nm layer of Co, followed by a 3–8 nm layer of Al_2O_3, topped with a 100 nm layer of NiFe, by sputtering with argon. The four MTJs in the 2 times 2 grid were designated Bit_{11}, Bit_{12}, Bit_{21}, and Bit_{22}, with each subscript referring to the corresponding word line and bit line, respectively, of the conducting paths at the nearest intersection. Setting word line 2 to an input excitation voltage while clamping bit line 2 to virtual ground through a read-mode switch caused the status of Bit_{22}, and only Bit_{22}, to appear at the output of the operational amplifier, thus proving the diode-free MRAM concept. According to Wang, the greatly improved memory density this development promises could boost the use of MRAM devices over semiconductor memories or magnetic disks in the future.

TIM PALUCKA

Stable, Guest-Free Clathrate Form of Crystalline Silicon Synthesized

A team of researchers from Jacksonville State University in Alabama and Arizona State University in Tempe, Arizona has reported the synthesis of a guest-free clathrate form of crystalline silicon. Optical and electrical measurements indicate that the properties of these structures are in reasonable agreement with existing theories predicting such new forms of crystalline silicon, with a wide (1.9 eV) and indirect bandgap.

Silicon clathrates were first obtained as metastable intermediate phases during thermal decomposition of alkali metal silicides. Previous forms of these silicon clathrates required the presence of clumps of alkali or alkaline earth metals as "guest" materials to prevent collapse of the struc-

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ture. Aiming for a structure of the Na_xSi_{136} type, this team has used a combination of successive vacuum "degassing" of Na from ionic Zintl phase sodium silicide, followed by density separation and centrifugation. As reported in the September 15 issue of *Physical Review B*, Na_xSi_{136} samples with low sodium concentrations (<4%) were washed in concentrated hydrochloric acid, dried and degassed at 430°C under a vacuum of 10^{-5} torr over a period of several days in order to lower the amount of sodium fractions. This process of washing and degassing was cycled several times, and ended with a final centrifuging in a dibromomethane-methanol solution for isolating the fraction with sodium content lower than 600 ppm.

X-ray diffraction analysis of this "open framework" form has revealed a volume per silicon atom of 23.01 Å^3, 16% greater than that of normal silicon (19.9 Å^3). The semiconducting nature is confirmed by electrical resistance measurements on cold-pressed discs of the sample. A bandgap of ~1.9–2.0 eV has been determined using reflection spectrometry.

The researchers said that such wide bandgap materials based on silicon could be developed for designing optoelectronics materials compatible with existing silicon technology if a precise control over form and stoichiometry can be developed.

Claudiu Muntele

Color Centers in Diamond Yield Potential Single Photon Source for Quantum Cryptography

A reliable single photon emission source can tremendously advance the field of quantum cryptography. The idea behind quantum encryption is that it is impossible to decipher the complete quantum state of a single particle. This method of coding will provide impenetrable security. So far, single photon emission sources for this purpose have been unreliable because of the low (liquid He) temperature requirement, the random triggering of emissions, and low collection efficiency (< 0.1%).

A group of researchers at the Optic Institute, the Charles Fabry Laboratory of the National Center of Scientific Research in France have pioneered a reliable, laser pulse-triggered, single photon emission source with a relatively simple setup. As reported on the September 1 issue of *Optics Letters*, the experiment is conducted with bulk diamond at room temperature. A 514-nm argon ion laser (10 mW) provided this trigger. The photon source is a piece of bulk diamond ($0.1 \times 1.5 \times 1.5$ mm^3) with nitrogen-vacancy defect centers.

The color center in the diamond is fabricated by the purchase of bulk diamond with nitrogen as an impurity. A 2-MeV electron beam with 3×10^{12} electrons/cm^2 was used to create the color center defects. Each defect consists of a substitutional nitrogen and a vacancy left by the nitrogen. The diamond sample is then vacuum annealed at 850°C for 2 h. The zero phonon wavelength is 637 nm, and excited state lifetime is 11.6 ns.

Data of the raw count rate were collected along with the image of the individual color centers. From the raw count rate, the correlation function of the defect center can be calculated. In this experiment, the correlation function equals zero only at $t = 0$,

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