Researchers in Singapore have created a room-temperature permanent magnet by mixing small amounts of carbon with the semiconductor zinc oxide. Although similar room-temperature dilute magnetic semiconductors (DMSs) have been made before, they were all semiconductors doped with copper. This new carbon-doped DMS is interesting because it could someday allow semiconductor manufacturing processes to be used to create spintronic circuits that process and store information using both the charge and spin of the electron (*Phys. Rev. Lett.* **99** 127201).

Computer chips and other semiconductor devices use the charge of the electron to process and store information. The electron also has a spin — which can be either “up” or “down” — and many physicists believe that spin could be used along with its charge to create electronic devices that could someday be faster and more efficient than today’s computer chips. A major stumbling block on the road to spintronics is the current lack of suitable materials that have both magnetic and semiconductor properties at room temperature. Such materials could, in principle, be used to create circuits in which electrons are controlled according to their two possible spin states.

Physicists first tried to create such materials by doping semiconductors with small quantities of magnetic metals such as manganese. Unfortunately, the resulting DMSs were magnetic only well below room temperature. To make matters worse, the metals did not disperse evenly throughout the semiconductor and instead formed clumps. This left researchers wondering whether the magnetism was occurring in the doped semiconductor, or in clumps of magnetic metal.

More recently, researchers created a room-temperature DMS by doping zinc oxide and gallium nitride semiconductors with copper. This was a significant breakthrough because copper is non-magnetic and therefore the observed magnetism must arise in the doped semiconductor, not in unwanted metallic clumps.

Now, a team led by Yuan Ping Feng and Jun Ding at the National University of Singapore
has created a brand new type of DMS by doping zinc oxide with carbon.

The materials were created by firing an intense laser pulse at a mixture of carbon and zinc-oxide powders. This caused some of the material to evaporate, coating a nearby sapphire substrate with films that were about 200 nm thick. By varying the amount of carbon powder in the target, the team was able to make zinc films with 0, 1 and 2.5% concentrations of carbon.

The team then measured the magnetic properties of the films using an extremely sensitive superconducting quantum interference device or SQUID. They found that both the 1% and 2.5% doped samples retained their magnetization to at least 400 K — about 100 degrees above room temperature.

According to Feng, the discovery of a carbon-doped DMS is significant because all other known DMS materials involve transition metals in which “d-shell” electrons are responsible for the magnetism. By contrast, magnetism in carbon arises from s and p-shell electrons, which makes it a completely new mechanism for physicists to explore.

“From an application point of view, it is hard to say which DMS will be more promising, but the discovery of room temperature ferromagnetism in carbon-doped ZnO opens a new direction in the search for new DMS”, said Ding. The team is now doing calculations to investigate magnetism in semiconductors doped with other light elements such as nitrogen.

About the author

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