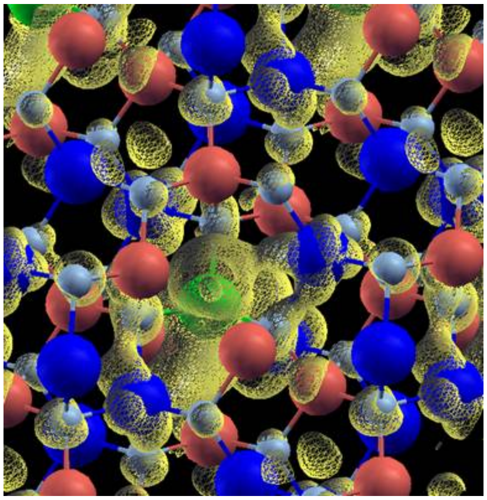
New Materials Approach to Spintronics

Researchers are investigating how to use the inherent spin of electrons and their associated charge and magnetic moment to produce semiconductor components. This approach, known as spintronics, represents a promising way to overcome the physical limits presented by current methods as semiconductor features shrink to the quantum scale. The material system that could potentially impact the development of spintronics is "dilute magnetic semiconductors," made by adding small amounts of magnetic atoms to common semiconductors. Until now, this method has not produced magnetic conductivity of the type needed in typical transistor devices.

In a modified approach, Lian Li and Michael Weinert of the University of Wisconsin, Milwaukee, have investigated the use of semiconductor materials that are intrinsically antiferromagnetic (i.e., the orientation of neighboring spins alternate and cancel each other out). Li and Weiner recently incorporated copper and oxygen atoms in a new compound, manganese germanium nitride (MnGeN2), and found that the desired transistor conductivity can be produced, with 100 percent of the spins aligned in the same direction—a characteristic essential for spintronics. In comparison, spins of magnetic metals such as iron are usually only about 50 percent polarized, with 75 percent spin-up and 25 percent spin-down. Introducing a small amount of non-magnetic atoms that selectively occupy only the up- or down-spin sites in the host material yields a net spin. This research shows that magnetic and electronic properties can be tailored through the selection of atoms introduced to the antiferromagnetic semiconductor material, and represents an important advance for realizing spintronic devices.



Crystal structure of manganese germanium nitride (MnGeN2) with vanadium as an intentionally added impurity atom. Color scheme: Dark blue–Manganese (Mn) atoms; Red–Germanium (Ge) atoms; Light blue–Nitrogen (N) atoms; Green–Vanadium (V) impurity atoms. This alternative, new class of material is being investigated by Li and Weinert for spintronic applications. Shown is the unique arrangement of atoms in MnGeN2, with an added vanadium atom that is predicted to prefer replacing only the spin-up Mn atoms. The yellow bubbles are calculated spin-up electron "clouds." Note that only half of the Mn atoms have such clouds around them (and none around the Ge). A similar calculated plot for spin-down (not shown) does not show any such clouds, indicating that 100 percent of the electrons are spin-up, which is an extremely attractive ingredient for spintronic device applications. Credit: Lian Li, University of Wisconsin, Milwaukee

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