Materials Research Science and Engineering Centers

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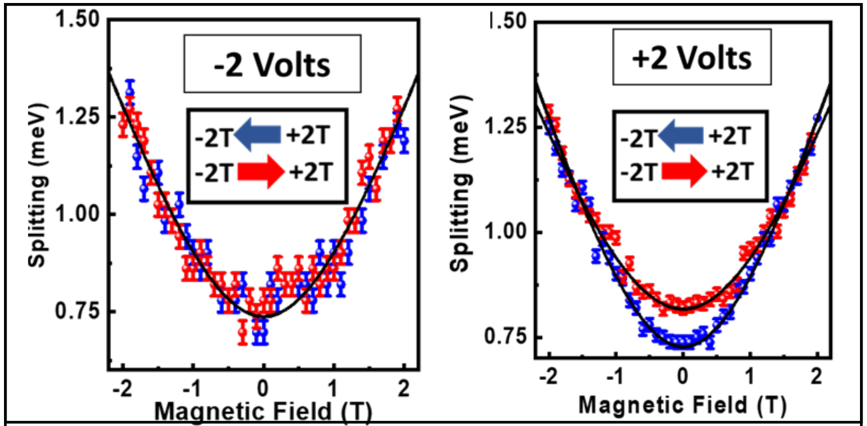
MRSEC DMR-1719875
2020

Control of Quantum Emitters by Magnetic Coupling

Cornell Center for Materials Research: an NSF MRSEC

Sources of single photons of light energy are called quantum emitters. The two-dimensional material WSe_2 is interesting as a host material for quantum emitters due to its coupled electron spin and valley physics and the possibility of controllably positioning quantum emitters with nanoscale precision. Magnetic interactions between atomically-thin ferromagnetic materials and bright emitters in WSe_2 have recently been leveraged to achieve low-temperature optical probes of magnetization.

A Cornell team is exploring the magnetic coupling of quantum emitters in WSe_2 and a few layers of Fe_5GeTe_2, which is ferromagnetic. The wavelengths of emitted light vary with magnetic field, and exhibit hysteresis: the variation depends on whether the magnetic field is increasing or decreasing. This hysteresis is the signature of coupling of the emitters to the ferromagnetic material. The Cornell group also showed that the hysteresis can be controlled by applying a voltage across the materials. The ability to control the quantum emitters will be valuable for applications.



The existence of hysteresis (right panel) and extinction of hysteresis (left panel) in the energy of quantum emitters demonstrates the ability to tune the energy levels and thereby the emission wavelength in WSe_2/ferromagnet-coupled systems.

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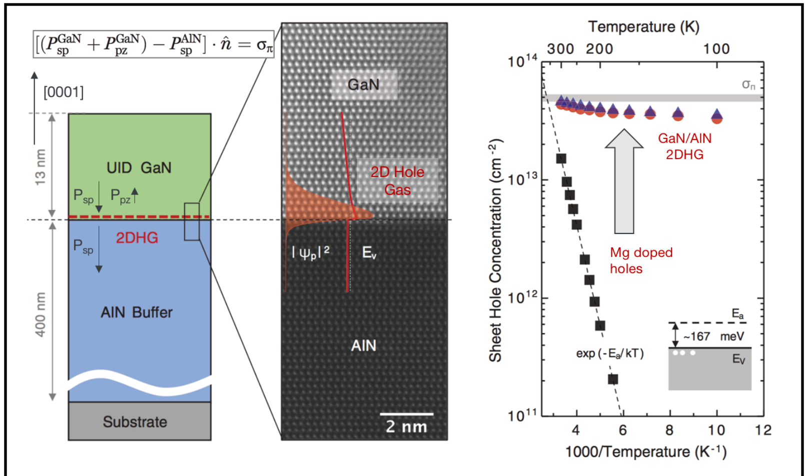
High-conductivity 2D holes induced by polarization discontinuity in GaN/AlN

Cornell Center for Materials Research: an NSF MRSEC

When an electrically-insulating material is grown on top of another insulator, the interface between the two insulators can be populated by mobile electrons. This has been achieved in interfaces that have a polarization discontinuity, such as AlGaN/GaN and $LaAlO_3/SrTiO_3$. It would be valuable to create a layer of mobile positive charges called holes, because electronic devices rely on charge carried by both electrons and holes.

A Cornell group's discovery of high-conductivity holes at the interface between GaN and AlN completes the hunt for electrons and holes induced by polarization in the column III-nitride semiconductors. These materials have enabled solid-state lighting and highly-efficient microwave and power electronics. This finding creates a way to explore the physics of closed-packed high-density electron-hole systems in this technologically-relevant material system.



Difference in internal polarization fields at the metal-polar GaN/AlN interface (shown above) gives rise to a negative sheet charge, which induces a layer of mobile positive holes– no chemical impurity doping is required. The resulting holes maintain their high densities at temperatures down to 10 degrees above absolute zero.

R. Chaudhuri *et al., Science* 365, 1454 (2019)