Force-Detected Nuclear Magnetic Resonance of Unstrained Gallium Arsenide with Applications in the Development of Spintronic Devices

Dr. Lee E. Harrell

Department of Physics
United States Military Academy
West Point, New York 10996

ARL Sponsor: Dr. Doran D. Smith

Optics Branch
Sensors and Electron Devices Directorate
U.S. Army Research Laboratory
Adelphi, Maryland

ABSTRACT:

Spintronics devices (i.e. devices that exploit the spin degree of freedom of the electron instead of, or in addition to, its charge) have already impacted technologies relevant to the Army, increasing hard drive capacity from 1 G to 20 G in a single step. Fast, high-density, low-power, nonvolatile computer memory based on spintronic devices will soon be competitive with conventional computer memory giving us zero boot time computers. Even more exciting is the possibility of dynamically configurable microprocessors based on programmable spintronic devices. However, to fully realize the potential of the spin degree of freedom of the electron in devices, carriers must be able to travel large distances and through a series of material interfaces while preserving both spin-orientation and phase information. Control of phase coherence is also important if spintronics technology hopes to deliver devices useful for quantum computing.

Methods for detecting the net effects of electron transport through complete devices have been demonstrated. However, these methods shed little light on the electron dynamics inside the device. Transit times for individual electrons make real-time, three-dimensional imaging of the inner workings of devices impractical, but in GaAs-based semiconductors, persistent spin-polarized currents leave an impression in the nuclear spin lattice that decays over a period of about 20 minutes. We have been developing force-detected magnetic resonance technology to image the resulting nuclear spin polarization in order to learn more about the dynamics of electron spins in these materials.

Our recent efforts have focused on refining our experimental techniques, identifying sources of experimental noise and developing our understanding of the magnetic resonance signals from ^{69}Ga in a test sample of unstrained GaAs. Both a narrow bulk peak and "slice" data, which represent a one-dimensional image of the nuclear polarization beneath the probe, have been observed for the case of thermal polarization of the nuclear lattice in a 5.2-T applied magnetic field at a temperature of 4.2 K (nominal). In the near future, we expect to replace the GaAs test samples with functioning spintronic devices.

KEY WORDS: Spintronics, Magnetic Resonance Imaging, Gallium Arsenide, Force-Detected Magnetic Resonance, Magnetic Resonance Force Microscopy

CONTACTS: Dr. Lee E. Harrell, Dept. of Physics, USMA, West Point, NY 10996
Tel: (845) 938-3548
Email: Lee.Harrell@usma.edu

Dr. Doran D. Smith, ARL, Adelphi, MD
Tel: (310) 394-1918
Email: ddsmith@arl.army.mil