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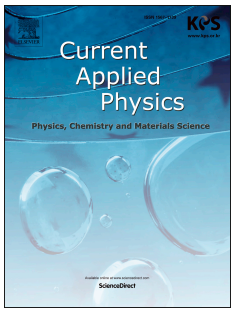

Spin-polarization and x-ray magnetic circular dichroism in GaAs

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Spin-Polarization and X-ray Magnetic Circular Dichroism in GaAs

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Abstract

The combination of angular spin momentum with electronics is a promising successor to charge-based electronics. The conduction bands in GaAs may become spin-polarized via optical spin pumping, doping with magnetic ions, or induction of a moment with an external magnetic field. We investigated the spin populations in GaAs with x-ray magnetic circular dichroism for each of these three cases. We find strong anti-symmetric lineshapes at the Ga L_3 edge indicating conduction band spin splitting, with differences in line width and amplitude depending on the source of spin polarization.

Recently, there has been intense interest in using spin-polarized carrier populations [1,2,3] in spintronic devices capable of entanglement based solid state quantum computation [4]. For these applications, the generation, propagation, and detection of spins in materials such as GaAs is of paramount importance. Several methods for generating polarized spins in GaAs have been demonstrated. Early experiments demonstrated spin pumping using optical techniques and established the role of nuclear spins in electronic spin dynamics [5,6,7,8]. In recent years, spin polarization has been demonstrated using electrical injection [9,10] and strong external bias fields [11]. Finally, doping of GaAs with magnetic ions such as Mn^{2+} has been shown to polarize the conduction band concurrently with the formation of ferromagnetic order [12]. While these experiments have demonstrated generation of spin polarized carriers and provided important information on the influence of spin on the band structure, the spin resolved GaAs conduction band (CB) structure while subject to optical spin pumping remains unexplored. In this article, we show that a spin carrier population induced by optical pumping can be detected via high sensitivity x-ray magnetic circular dichroism (XMCD) at the Ga L_3 edge. We compare the spectra at different doping levels to those due to spin populations from alloying with Fe and by application of an external magnetic field.

Four series of XAS and XMCD spectra were measured at the Ga L_3 (1117 eV) edge using beamline 4-ID-C at the Advanced Photon Source. Data were collected by monitoring the photocurrent (TEY) from the sample. In the first series, spin polarization was

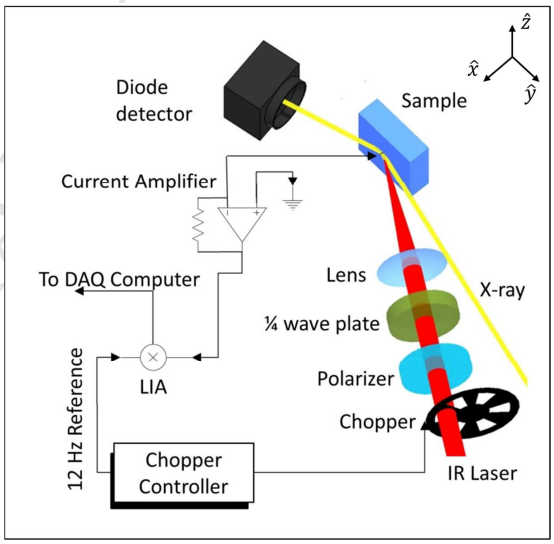

Figure 1. Experimental set-up for x-ray probing of optically excited spin carriers in GaAs. A diode laser just above the bandgap energy (1.5 eV) is used to create a non-equilibrium carrier population in a GaAs (100) wafer at 10 K. For phase sensitive detection, the laser beam is modulated using a mechanical chopper at 12 Hz with circular polarization generated using a linear polarizer and quarter-wave plate. X-rays at the Ga L_3 absorption edge (1116 eV) are incident on the sample at angles below 7°, and the angle between x-ray and laser beams is 45°**.** The x-ray induced photocurrent is amplified with a current pre-amp and monitored with a LIA.

generated using an external 6.5 T field. In the second and third, optical excitation from an 850 nm circularly polarized laser was used to excite carriers in n-type GaAs at carrier concentrations of 10^{16} and 10^{18}/carrier concentration, respectively. The 1st and 2nd series were silicon doped (carrier concentration 10^{18}/cm^3) GaAs