NUCLEAR SPIN-LATTICE RELAXATION IN N-GaAs CLOSE TO THE METAL-INSULATOR TRANSITION

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Dynamic electron spin polarization and associated nuclear spin polarization is of considerable interest in semiconductors, particularly in GaAs, with potential application in the development of spintronic devices. Nuclear spin-lattice relaxation mechanisms can be important in determining the nuclear polarization that is achieved. The coupling of electron and nuclear spins in n-GaAs close to the metal-insulator (MI) transition changes significantly as the dopant concentration n is increased through the MI critical concentration n_C. (n_C=1.2x10^{16} cm^{-3} in zero external field.) There appears to have been no previous comprehensive study of the nuclear spin-lattice relaxation in GaAs as a function of *T* and *H* close to the MI transition. We have measured the ^{71}Ga spin lattice relaxation time over a wide range of temperature and magnetic field for concentrations above and below n_C The ^{71}Ga relaxation rates ^{71}W measured as a function of magnetic field (1 – 13 T) and temperature (1.5 – 300 K) for n-GaAs samples with n = 5.9x10^{15}, 7x10^{16} and 2x10^{18} cm^{-3} are shown in Fig. 1. Note the dramatic difference in the temperature and field dependence between the samples doped below the MI transition and those above it. The changes correspond to the evolution of localized donor states into itinerant states close to the bottom of the conduction band. Korringa-like relaxation is found in the metallic samples for *T*<30 K and power law dependence at lower n. For *T*> 30 K phonon-induced nuclear quadrupolar relaxation is dominant in all samples including semi-insulating material. Knight shift measurements made on the 2x10^{18} cm^{-3} sample using magic-angle spinning, confirm a very small value for the hyperfine coupling constant and permit comparison of the Korringa product with theoretical predictions. At lower n, local moments play an important role in relaxation producing striking changes in the *H* dependence of ^{71}W. A model for nuclear relaxation in the vicinity of n_C has been developed incorporating nuclear spin diffusion and antiferromagnetic interaction of donor spin pairs with a distribution of exchange couplings. Allowance is made for changes in the magnetic length as *H* is increased. The results provide insight into the spin dynamics in this interesting and important system.

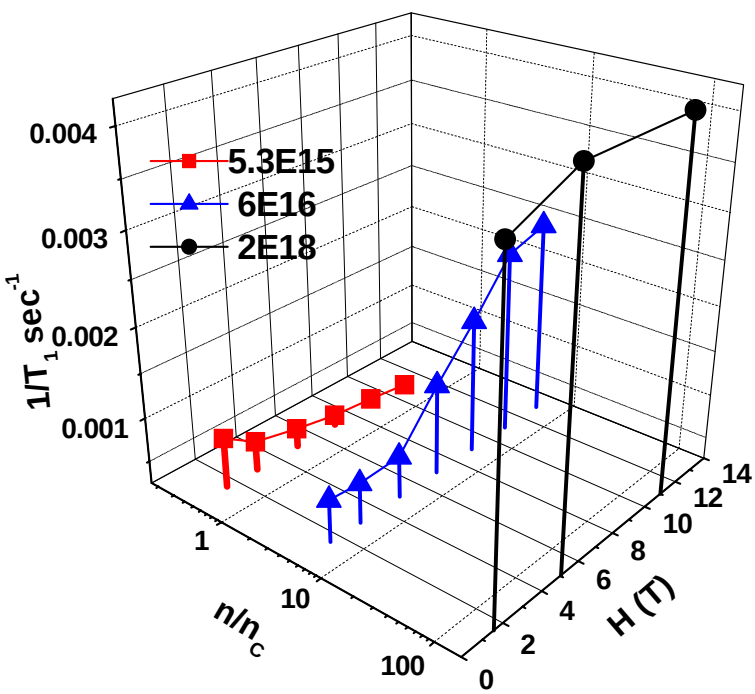

Fig. 1. ^{71}Ga inverse nuclear spin lattice relaxation time $1/T_1$ in GaAs as a function of *T* and *H* for dopant concentrations above and below the MI transition. n_c is the MI critical concentration 1.2x10^{16} cm^{-3} at zero field.