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Microsecond spin-flip times for localized donors in GaAs

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One of the central tasks in developing spin-based quantum computing is the development of materials which have long spin lifetimes. Observations of long electron spin lifetimes (hundreds of ns) in n-type GaAs dating back to Kikkawa and Awschalom in 1998 [1] have stimulated much excitement in the field, and many groups have similarly made observations of the inhomogeneous T_2^* lifetime of electrons in GaAs in the ns regime. The homogeneous dephasing time, T_2, has not yet been measured, although it is expected to be much longer. Here, a series of measurements of lifetimes [2] are described for donors in lightly n-type GaAs doped at 3E14, 1E15, and 3E15 cm^{-3} that mimic spin memory in doped quantum dots. Hanle effect measurements yield T_2^* at close to 0T, magnetic resonance measurements provide T_2* at 40 mT, and Kerr rotation measurements provide T_2^*at higher fields. The measured T_2^* values for the 3E14 sample are consistent with full electron localization. A new pump-probe technique using electronic delays between pulses has been used to measure spin lifetimes into the μs range. This time-resolved technique provides measurements of the spin-flip time (often labeled T_S, which is essentially the same as T_1) for two of the samples at a range of fields and temperatures. T_S is greater than 1 μs for B>0.6T at 1.5K and for B>2.5T at 6 K. Since T_2 is limited by the spin-flip time, these measurements show the range of temperature and magnetic field where very long T_2's are possible. [1] Phys Rev Lett **80**, 4313 (1998). [2] J.S. Colton et al., Phys Stat Sol B **233**, 445 (2002); Phys Rev B **67**, 165315 (2003); Phys Rev B **69**, 121307(R) (2004); Solid State Comm **132**, 613 (2004).

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