CHARACTERIZATION OF STRAIN AND STRAIN RELAXATION IN GAAS/SI COMPOSITES BY OPTICAL DYNAMIC NUCLEAR POLARIZATION ENHANCED NUCLEAR MAGNETIC RESONANCE

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We present a new NMR methodology for the measurement of lattice strain and strain relaxation in GaAs that utilizes optical dynamic nuclear polarization (ODNP). Stain is induced by epoxy-bonding GaAs crystals to Si wafers at 400 K. Due to differential thermal contraction upon cooling the sample to ~5K, a biaxial tensile strain was induced. Strain is manifested as a quadrupole splitting in the NMR resonance, and the observed quadrupole splitting is proportional to the strain in the volume of the sample within the penetration depth of the laser light, which above the bandgap is less than one micrometer.[1] Hence, this technique is sensitive to the strain localized near the surface of the GaAs. The dominant mechanism of strain relaxation in the composite samples was identified by bonding GaAs crystals to Si supports of two different thicknesses and thinning the GaAs to a series of different thicknesses using selective chemical etching. Here we demonstrate that the relaxation of the observed strain with GaAs thickness is consistent with mechanical bowing of the entire composite structure.

To investigate the effect of strain on ODNP due to strain-induced changes in the electronic band structure, the photon energy dependence of the ODNP-NMR action spectrum was recorded. Strain lifts the degeneracy of the light hole and the heavy hole bands near $k=0$ [2] which can result in state selective pumping of electrons from the light hole to the conduction band at low photon energies or from the heavy hole to the conduction band at high photon energies. The electron spin polarization under ODNP conditions was estimated from the theoretically calculated absorption coefficients and the nuclear spin polarization was calculated based on the standard scalar electron-nuclear spin cross-relaxation model. [3,4] These results demonstrate that the combination of ODNP-NMR measurements with electronic band structure calculations provides a new way to probe the effects of strain in III-V semiconductors with promising applications.

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[1] M. Sturge, *Phys. Rev.* 127, 768 (1962)
[2] Y. Sun, *et. al.*, *Strain Effects in Semiconductors: Theory and Device Applications* (Springer, 2010).
[3] P.L. Kuhns et al., *Phys. Rev. B.* 55, 7824-7830 (1997).
[4] R.M. Wood et al., *Phys. Rev. B.* 90, 155317 (2014)

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