Effect of thermal annealing on hole spin relaxation of Be-doped InGaAsP bulk

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The spin relaxation of semiconductors has attracted considerable attention owing to the enormous potential of spin-based devices, the so-called "spintronic devices".[1] Previously, we reported the effect of thermal annealing on the electron spin relaxation of Be-doped InGaAsP bulk grown on InP substrate observed by time-resolved pump and probe measurement.[2,3] Here, we report the sub-picosecond spin relaxation in 800 °C-annealed and unannealed Be-doped InGaAsP bulk grown on InP substrate.

These samples contain a 1000-nm-thick Be-doped InGaAsP grown on InP substrate by molecular beam epitaxy. The Be concentration is 2×10^{17} cm^{-3}.After the growth, one of these samples was annealed at 800 °C. The other was unannealed. The spin relaxation process was observed by pump and probe measurement.[4]

A Ti:sapphire laser with an optical parametric oscillator was used as the optical source. The pump beam was chopped by an electro-optic modulator at 1.9 MHz to avoid optical noise in the low-frequency region. In the spin-dependent pump and probe measurements, the laser energy was tuned near the photoluminescence peak. The time resolution in the measurement was subpicosecond and determined by the optical pulse width.

Figure 1(a) shows the observed time evolution of spin-dependent reflectance of cross-linear (I_{CL}) and anti-circular (I_{AC}) polarization of the annealed sample at 10 K for the excitation power of 30 mW at the excitation wavelength of 1118 nm. Cross-linear polarization indicates the population change without spin polarization. Anti-circular polarization indicates the population change of up spin polarization. Figure 1(b) shows the time evolution of spin polarization of annealed sample which is obtained by $(I_{CL}\text{-}I_{AC})/ I_{CL}$. The two spin relaxation times, which are twice the relaxation time of the spin polarization,[4] are obtained by the double exponential fitting. The faster spin relaxation time τ_s is 0.71 ps at 10K. This fast spin relaxation can be attributed to hole spin relaxation. Figure 2 shows temperature dependences of hall spin relaxation time of annealed and unannealed Be-doped InGaAsP bulk. Hole spin relaxation times of unannealed sample are faster than those of annealed sample. It has been theoretically predicted that hole spin relaxation is affected by Elliott-Yafet process.[5] EY process causes spin flip by impurity scattering and phonon scattering.[6,7] This difference indicates that the 800 °C-thermal annealing extends the hole spin relaxation time by reducing carrier scattering.

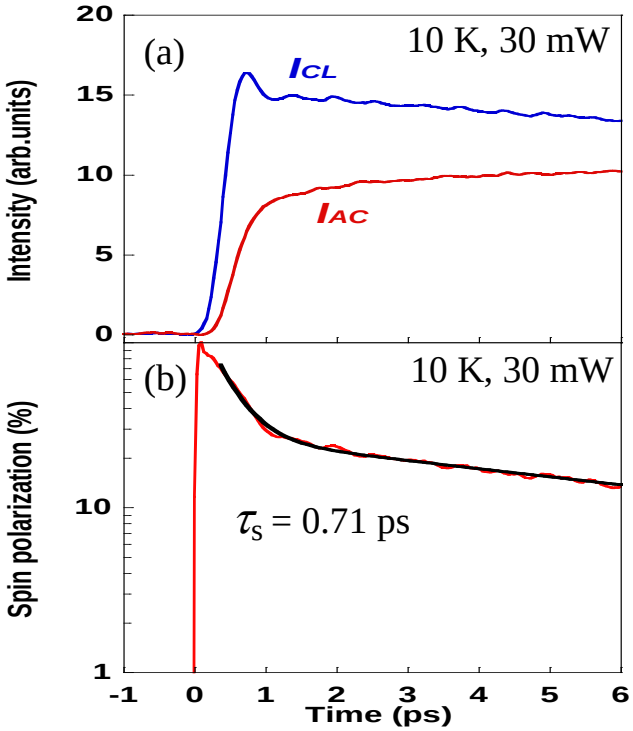

Fig.1 Time evolutions of (a) spin-dependent reflection intensity and (b) spin polarization in 800 °C annealed InGaAsP bulk at 10 K for the excitation power of 30 mW at 1118 nm.

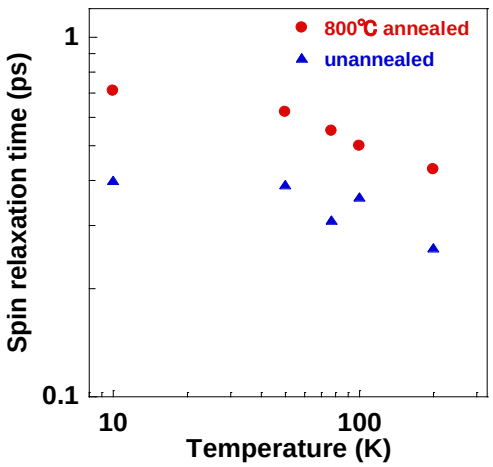

Fig.2 Temperature dependences of hole spin relaxation time of Be-doped InGaAsP bulk for the excitation power of 30 mW.

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