全光核磁気共鳴による AlGaAs バルクでの核分極ダイナミクスの研究

Study on nuclear spin polarization dynamics in n-doped AlGaAs bulk
by using all-optical NMR technique

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Introduction: Unlike quantum dots and quantum wells, in bulk semiconductors, the electron wave function is considered to be uniformly distributed over the sample and the nuclear spin polarization (NSP) generated by hyperfine interaction (HFI) should be small due to low electron localization. However, in bulk $Al_{0.15}Ga_{0.85}As$, a huge nuclear magnetic field B_N corresponding to a large NSP is found [1]. Comparing to GaAs (B_N ~100 mT) [2], the B_N can be slowly (~600 s) generated up to 1.4 T in $Al_{0.15}Ga_{0.85}As$. In order to study the formation dynamics of NSP in AlGaAs bulk, we applied All-Optical NMR (AONMR) technique. With AONMR, we can analyze each nuclear species separately and understand the dynamics better.

Sample & Experiment: The bulk $Al_{0.15}Ga_{0.85}As$ sample was grown on (001) SI-GaAs substrate with a doping density of $N_e=1\times10^{16}$ cm^{-3}. The whole experimental system is based on a time-resolved Kerr rotation (TRKR) system. The measurements were performed at 10 K under an external magnetic field applied at θ = 20° to the sample growth direction. By fixing the delay time of the probe beam and the modulation frequency of pump beam intensity, the AONMR signals were detected as a function of magnetic field strength.

Results & Discussion: Comparing to AONMR signals in GaAs, the resonant peaks in $Al_{0.15}Ga_{0.85}As$ are broader than those in GaAs (Fig.1), indicating the slow formation of NSP in $Al_{0.15}Ga_{0.85}As$. One reason for this could be the following; the slow nuclear spin diffusion due to quadrupole splitting of AlGaAs results in a higher saturation value of NSP, but a long formation time should be required to reach that steady-state value. By changing the modulation frequency of the pump beam, we can obtain the gyromagnetic ratio of each element in the sample (Fig.2). High-resolution scan (Fig.3) provides information on the depolarization and formation time of each nuclear species, and helps to understand what role each nucleus plays in forming a huge nuclear magnetic field.

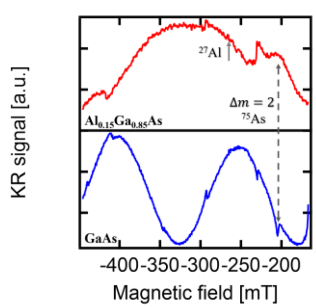

Fig.1 AONMR comparison of GaAs[2] and $Al_{0.15}Ga_{0.85}As$.

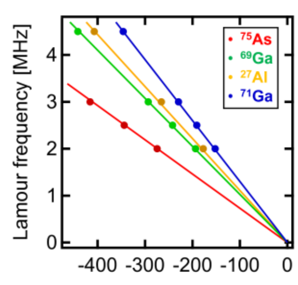

Fig.2 Gyromagnetic ratio measured by AONMR.

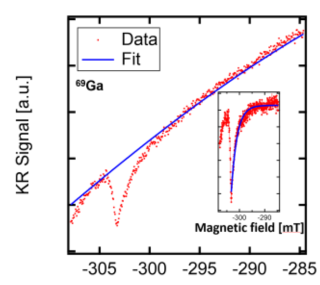

Fig.3 High-resolution AONMR of ^{69}Ga.

[1] 斉藤圭吾 他，第 57 回応用物理学会北海道支部学術講演会 B-8 (2022 年 1 月 8 日，オンライン).
[2] 鍛治怜奈 他，第 57 回応用物理学会北海道支部学術講演会 B-7 (2022 年 1 月 8 日，オンライン).