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ESR Study of Spin System in Phosphorus Doped Silicon as Candidate of Quantum Computing Device

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Recently the quantum computer is one of the most fascinating fields in the study of physics. Among many physical systems as the quantum computer device the spin system in phosphorus doped silicon (P-doped Si) is proposed as a powerful candidate device.[1] In order to investigate the behavior of the spin system in P-doped Si, we are making experiments of NMR on ^{31}P nucleus and ESR on donor electron. Here, we report results of ESR experiment performed under the high frequency and the high magnetic field. The ESR experiment of donor electron in P-doped Si has already been carried out in 1960's under low magnetic field at X-band microwave frequency region. According to their results, for the sample with donor concentration less than 3×10^{17} cm^{-3} the spectrum of donor electron consists of two lines. The separation of these two lines in 42 G caused by the hyperfine interaction was ^{31}P nucleus spin. The line width of each line is 2.5 G as the effect of hyperfine interaction with ^{29}Si nuclear spins. For the sample with donor concentration more than 3×10^{17} cm^{-3} the spectrum becomes a single line due to the hopping motion or impurity conduction of donor electron.

The present ESR experiment was performed at liquid helium temperature in P-doped Si with donor concentrations ranging from 2.8×10^{15} cm^{-3} to 6.7×10^{17} cm^{-3}. The range of microwave frequency and the magnetic field is from 35 up to 110 GHz and 1 to 3 T, respectively. The results were almost same as those reported previously, but a small asymmetry in the spectral line observed under the high magnetic field whose origin is not clear at this point. For the future work we are planning to investigate the effect of the electric field on the hyperfine interaction between ^{31}P nuclear spin and the donor electron spin by observing the ESR spectral line shift with applied electric field.

[1] B. E. Kane, Nature **393**, 133 (1998).