Electrically-detected ESR in silicon nanostructures inserted in microcavities

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We present the first findings of the new electrically detected electron spin resonance technique (EDESR), which reveal single point defects in the ultra-narrow silicon quantum wells (Si-QW) confined by the superconductor delta-barriers [1]. This technique allows the ESR identification without application of an external cavity as well as a high frequency source and recorder, with the measurements of the only response of the magnetoresistance caused by the microcavities embedded in the Si-QW plane. The ESR lines with the characteristic hf splitting of 4.1 mT that are related to the single phosphorus centers close to the p+-n junction area are observed. Besides, the spin-dependent scattering of 2-D holes is revealed by measuring the phosphorus line splitting that is to be evidence of the exchange interaction, which is similar to the effect of zero-field splitting in 1-D channels. The high sensitivity of the new EDESR technique is confirmed by measuring the NL8 spectrum that identifies residual oxygen thermodonors, TD+ - state, in the p-type Si-QW. This center of the orthorhombic symmetry has been also found by the ordinary EDESR method in the sandwich structure discussed here. The central lines in the EDESR spectrum are slightly different from the NL10 spectrum that is related to the neutral thermodonor containing a single hydrogen atom. Nevertheless, this EDESR spectrum appears to identify the hydrogen-related center in the p-type Si-QW, because its characteristic hf splitting, 23 MHz, corresponds to the hf hydrogen splitting. Different phases of the hf lines that result from the hydrogen-related center seem to result from the high spin polarization of holes in 1-D channels [2]. The 23 MHz hf splitting was also verified in the EDESR line with a g-value of 2.07 that seems to be related to the Fe^0 center. The high sensitivity of the EDESR technique allowed the studies in weak magnetic fields that are of importance for the measurements of the hf splitting for the centers inserted in Si-QWs, which are characterized by the large g-values such as the Fe^+ center and the trigonal erbium-related center. Since the measurements of magnetoresistance were performed without any light illumination and injection of carriers from the contacts, the EDESR effects appear to result from the spin-dependent scattering of spin-polarized holes from the single paramagnetic centers at the edge channels of the S–Si-QW–S sandwich structures. Therefore the resonant positive magnetoresistance data appear to be interpreted here in terms of the interference transitions in the diffusive transport of free holes, respectively, between the weak antilocalization regime ($\tau_S > \tau_\varphi > \tau_m$) in the region far from the ESR of a paramagnetic point defects located inside edge channels and the weak localization regime ($\tau_\varphi > \tau_S > \tau_m$) in the nearest region of the ESR of that defect.

[1] N.T. Bagraev et al., Physica C **468,** 840 (2008).
[2] N.T. Bagraev, et al., Journal of Modern Physics **2**, 256 (2011).