Terahertz Emission from Quantum-Sized Silicon p^+ - n Junctions

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***Abstract*—We present the first findings of the THz emission from the ultra-narrow p-type Si quantum well confined by the superconductor (SC) δ-barriers on the n-type Si(100) surface. The EL spectra revealed by the voltage applied along the Si-QW plane appear to result from the value of the SC energy gap.**

I. Introduction And Background

The device has been prepared on the n-type Si (100) surface within frameworks silicon planar technology. Making a mask and performing photolithography after preliminary oxidation, the short time diffusion of boron was used to obtain the ultra-shallow p+-n junctions [1]. The cyclotron resonance measurements as well as the infrared and local tunneling spectroscopy data have shown that the p+-boron diffusion profile represent the ultra-narrow p-type silicon quantum well (Si-QW), 2 nm, confined by the δ-barriers, 3 nm, heavily doped with boron on the n-type Si (100) surface (see Figure 1). The SIMS and STM studies have shown that the δ-barriers heavily doped with boron, (concentration $5\cdot10^{21}cm^{-3}$), represent really alternating arrays of silicon empty and doped dots, with dimensions restricted to 2 nm. This concentration of boron seems to indicate that each doped dot located between empty dots contains two impurity atoms of boron. The EPR studies show that these boron pairs are the trigonal dipole centers, B(+) - B(-), that contain the pairs of holes, which result from the negative-U reconstruction of the shallow boron acceptors, 2B(0) => B(+) + B(-). The electrical resistivity, magnetic susceptibility and specific heat measurements demonstrate that the δ-barriers heavily doped with boron exhibit the superconductor properties, T_c = 145K, H_{c2} = 0.22 T, thereby confining the Si-QW embedded in a quantum-sized superconducting p-n junction on the Si (100) surface.

II. Results

This device appears to allow the light-emission due to the longitudinal bias voltage eV_{ds} and $2eV_{ds}$ that are created by the stabilized drain-source current [2]. The corresponding series of the EL spectral lines is revealed by the voltage applied along the Si-QW plane, which is in an agreement with the value of the superconducting energy gap, 0.044 eV [1]. Besides, the terahertz spectra exhibit the phase shifts for the modulation frequencies, 129 and 9.3 GHz, which seem to result from the transitions between the excited states of the boron dipole centers under the V_{xy} applied voltage (see Figure 2).

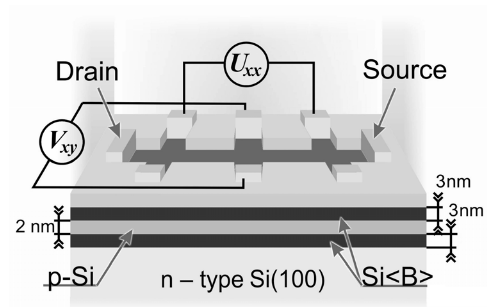

Figure 1. Device schematic, showing the perspective view of the silicon device structure performed within the frameworks of the Hall geometry. The silicon sandwich represents the p-type silicon quantum well confined by the δ-barriers heavily doped with boron on the n-type Si (100) surface. The source and drain Ohmic contacts are marked by S and D, respectively. The terahertz emission is caused by the drain-source current, Ids.

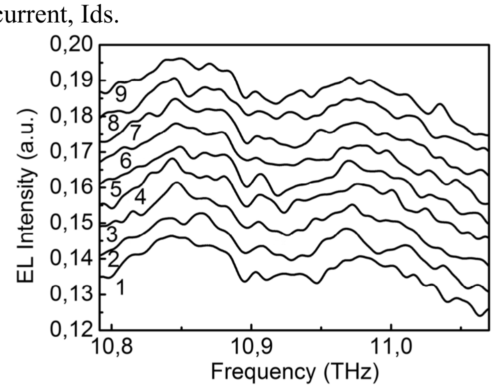

Figure 2. The terahertz spectra due to the light-emission induced by the longitudinal applied bias voltage; T = 300 K; I_{ds} = 40 mA; The modulation of the spectra shows the presence of the emission at 0.129 THz. The phase shift of the 9.3 GHz modulation is controlled by biasing the voltage applied to the Hall contacts, V_{xy} (mV): 1 - -250; 2 - -150; 3 - -50; 4 – 0; 5 - +50; 6 - + 100; 7 - +150; 8 - +200; 9 - + 250.

References

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