Quantum Oscillation and Decoherence in Triangular Antidot Lattice

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Extensive studies have been performed to elucidate electronic transport phenomena in two-dimensional electron gas (2DEG) at semiconductor heterointerface subjected to periodic potential modulations (lateral superlattices). Antidot lattices provide an experimental stage for exploration of interesting mixture of semiclassical and quantum transport. Quantum transport is manifest in Aharonov-Bohm (AB)-type oscillations[1] and Altshuler-Aronov-Spivak (AAS) oscillations[2]. In this work, we study these different types of quantum oscillations in triangular antidot lattice samples. We focus on decoherence at finite temperatures for each types of quantum oscillatory phenomena, and make comparison with the case of single quantum ring.

Samples used in the present study were fabricated from a GaAs/AlGaAs single heterojunction 2DEG wafer with electron density $n_s = 3.6 \times 10^{15}\mathrm{m}^{-2}$ and mobility $\mu = 68\mathrm{m}^2/\mathrm{Vs}$. The corresponding Fermi energy was $E_F = 12.9\mathrm{meV}$ and the elastic mean free path $l = 6.8\mu\mathrm{m}$. Triangular antidot lattice was fabricated on conventional Hall bar by standard electron beam lithography and wet chemical etching. The lattice constant was $a = 960\mathrm{nm}$ and the geometrical aspect ratio was $d/a = 0.6$ (sample #1) and 0.7 (#2), d being the antidot diameter.

Figure 1 shows the magnetoresistance of sample #2 at 30mK. Figure 1-B gives an expanded view of the low field range. The lower curve shows the oscillatory part of the magnetoresistance after subtracting the smooth part. The AAS oscillation around zero field and the AB-type oscillation at somewhat higher fields are clearly seen. The periods of these oscillations are consistent with and per unit cell area. Figure 1-C is an expanded view of the trace near the peak at $B = 4.85\mathrm{T}$ corresponding to the filling $\nu = 2.5$, which shows a clear AB-type oscillation. Similar oscillatory behavior has been also seen for other peaks marked by red arrows in Fig.1-A. The period of these high field oscillation is consistent with the area of the antidot (with an appropriate allowance of the depletion region), and systematically increases for higher magnetic field (lower filling) reflecting the change in the position of the outermost edge channel.

We have investigated the temperature dependences of these three types of quantum oscillation observed in the triangular antidot lattice. Figure 2-A shows the temperature dependences of the AAS oscillation amplitude. The amplitude of the fundamental period ($h/2e$) is shown together with those of the higher harmonics. The relative amplitudes of the $h/2e$, $h/4e$, and $h/6e$ components are consistent with the expected dependence $\propto \exp(-nL/L_\phi)$, where L is the circumference of the antidot and n is the harmonic index. The observed temperature dependence can be fitted to $\propto \exp\{-(T/T_c)^{1.5}\}$ which implies $L_\phi \sim T^{-1.5}$. The may be contrasted with the behavior $L_\phi \sim T^{-1}$ reported for single ring samples[3].

Figure 2-B and C shows the temperature dependence of the amplitude of the AB-type oscillations in the low field region and that in the high field region, respectively. The AB-type oscillations both in the low field and high field regions obey the temperature dependence, $\propto \exp(-T/T^*)$. The AB-type oscillation phenomenon in macroscopic samples of antidot lattice is different in nature with the canonical AB oscillation in a single ring, because the latter is susceptible to ensemble averaging. The AB-type oscillation in antidot lattice is thought to represent a magnetic-field-dependent fine structure of the density of state spectrum[4]. The characteristic temperature has been found to be $T^* = 0.69\mathrm{K}$ for the AB-type oscillation in the low field region. This value is in reasonable agreement with a calculated energy level spacing of the quantized orbits circumnavigating the antidot. The AB-type oscillation in the high field re-

gion turned out to be much more temperature sensitive. For those around $\nu = 2.5$, the obtained characteristic temperature was $T^* \approx 0.1\mathrm{K}$.

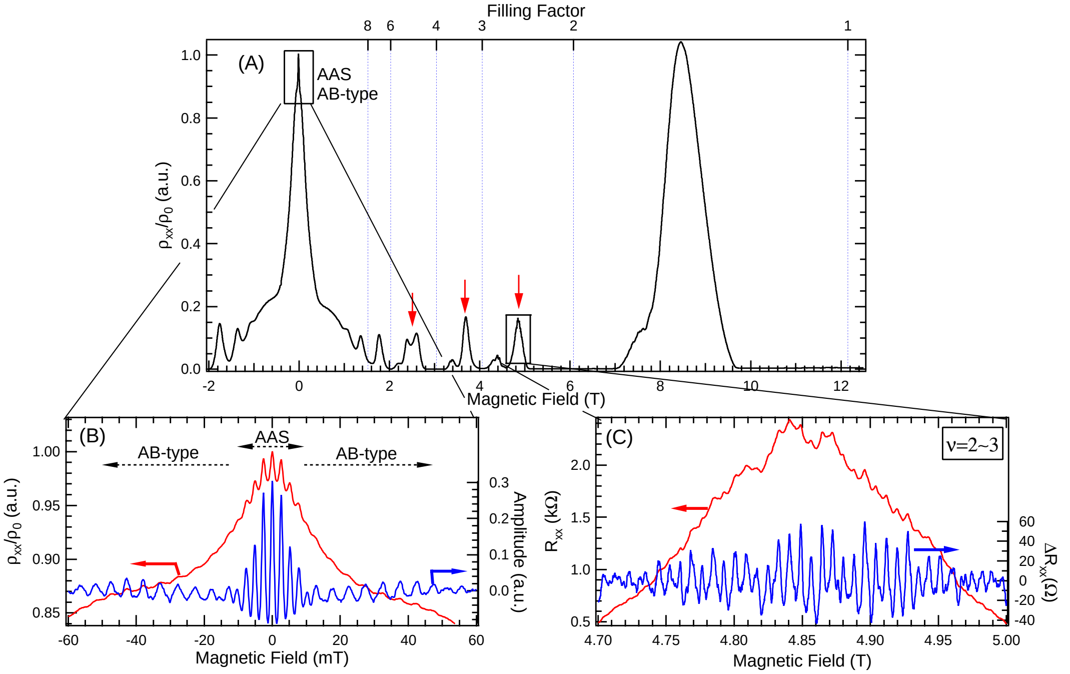

Figure 1: Magnetoresistance of sample #2 at 30mK

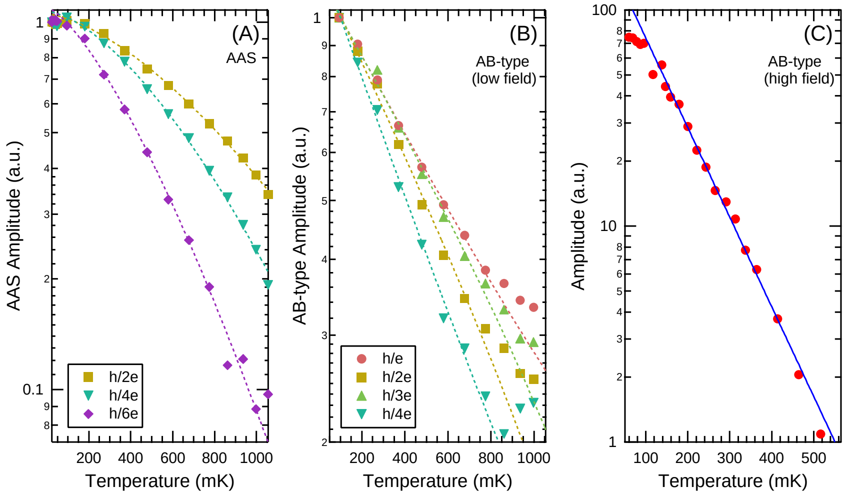

Figure 2: Temperature dependece of quantum oscillations.

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