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Resistivity of Two-Dimensional Systems in a Magnetic Field at the Filling Factor ν = 1/2

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Experimental data on the diagonal resistivity ρ_{xx} of GaAs/AlGaAs heterostructures in a magnetic field at the filling factor $\nu = 1/2$ have been compared with the existing theoretical predictions [B. I. Halperin et al., Phys. Rev. B **47**, 7312 (1993) and F. Evers et al., Phys. Rev. B **60**, 8951 (1999)]. The experimental results have been found to follow the relation $\rho_{xx}(1/2) \propto n^{-2}d^{-1.64}$, which disagrees with the predictions.

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The expression for the diagonal resistivity ρ_{xx} of two-dimensional systems in a magnetic field at the filling factor $\nu = nh/eB = 1/2$ was obtained in [1] based on the composite fermion theory. The composite fermions are scattered by a random magnetic field induced by ionized impurities. The impurity concentration n_i in the ideal selectively-doped two-dimensional sample is equal to the electron density n and, at $\nu = 1/2$,

$$\rho_{xx}(1/2) \sim \frac{1}{k_F d}\frac{h}{e^2}. \tag{1}$$

Here, $k_F = \sqrt{4\pi n}$ is the wavenumber of the composite fermions at the Fermi level and d is the spacer thickness. A more general and detailed analysis of $\rho_{xx}(1/2)$ carried out in [2] yields the same but more accurate result for the $n_i = n$ case:

$$\rho_{xx}(1/2) = 1.0\frac{1}{k_F d}\frac{h}{e^2}. \tag{2}$$

In this work, Eq. (2) is compared with the published experimental data [3–16] on $\rho_{xx}(1/2)$ of single GaAs/AlGaAs heterojunctions with one doped layer.

We used the $\rho_{xx}(1/2)$ data for the gateless samples with the mobility $\mu > 40$ m^2/V s, the electron density $6 \times 10^{14} \le n < 5 \times 10^{15}$ m^{-2}, and the spacer thickness $20 \le d \le 240$ nm. Some samples [3–8] were irradiated by light, the others [9–16] were not. The data for only two samples were not used. The fractional quantum Hall effect in these samples was substantially weaker than that in the other samples with the close parameters. For the sample used in [16] whose resistance depended on its prehistory, we used the data for the minimum-disorder case.

The experimental data are compared with Eq. (2) in Fig. 1 where we plotted the experimental and theoretical dependences of $\rho_{xx}(1/2)k_F$ on d (let us remind that $k_F = \sqrt{4\pi n}$). The experimental points exhibit a large spread not very far from the theoretical line. We tried to plot the experimental data in the form $\rho_{xx}(1/2)n^p(d)$ with different integer and half-integer p values and to fit them by linear functions in the log–log scale. The best fit was obtained for $p = 2$ and the exponent of d equal to -1.64 (see Fig. 2). This corresponds to the expression

$$\rho_{xx}(1/2) = \alpha n^{-2}d^{-1.64}, \tag{3}$$

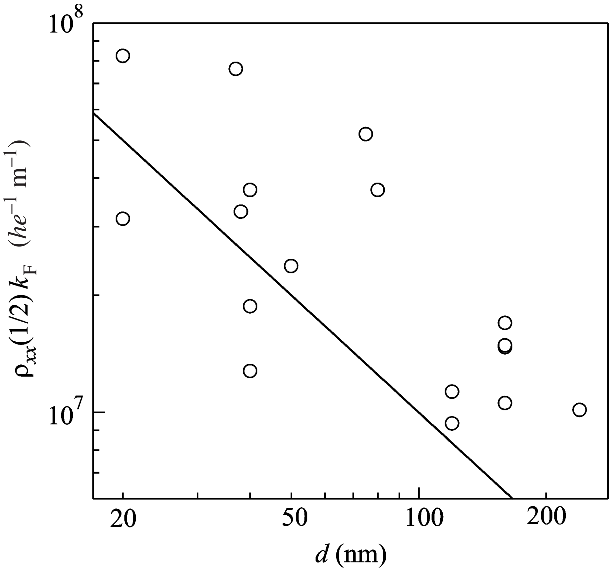

Fig. 1. $\rho_{xx}(1/2)k_F$ versus the spacer thickness d. The circles are the experimental data, and the straight line corresponds to Eq. (2).

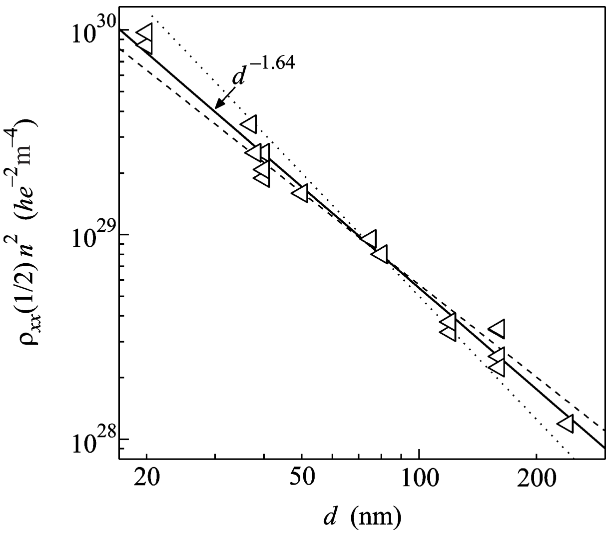

Fig. 2. $\rho_{xx}(1/2)n^2$ versus the spacer thickness d. The triangles are the experimental data, and the solid line is the linear fit of the data in the log–log scale. The (dashed line) $d^{-1.5}$ and (dotted line) d^{-2} dependences are also shown for comparison.

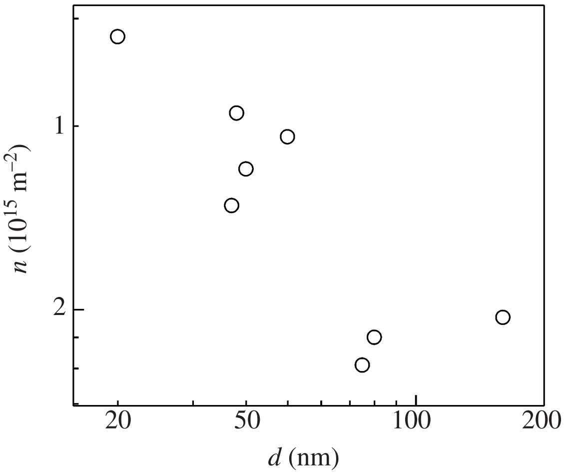

Fig. 3. Electron density n in non-irradiated samples versus the spaces thickness d.

where $\alpha = 1.6 \times 10^{17}$ m$^{-2.36}$. The straight lines corresponding to $d^{-1.5}$ and d^{-2} are also shown in Fig. 2. They display somewhat poorer agreement with the experimental data. The coefficient α is independent of the magnetic field. At a given filling factor $\nu = nh/eB = 1/2$, the magnetic field is unambiguously related to the electron density n. The length corresponding to α is $l = \alpha^{-1/2.36} = 5.2 \times 10^{-8}$ m.

Figure 2 indicates that the large spread in the data points in Fig. 1 does not result from the presence of random impurities or defects in the samples. The regular arrangement of the points in Fig. 2 calls for a new explanation of the electron transport in the magnetic field with $\nu = 1/2$.

Note that on average for non-irradiated samples, n decreases with an increase in d (see Fig. 3), but the relative spread of the data points in Fig. 3 is much larger than that in Fig. 2.

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