Fractional quantization of the Hall resistivity in silicon metal-insulator-semiconductor structures

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Anomalies have been observed in components of the resistivity tensor in silicon metal-insulator-semiconductor structures. These anomalies correspond to fractional values of the Landau-level filling factor, $\nu = 4/3$ and $\nu = 2/3$.

Anomalies are observed in the components ρ_{xx} and ρ_{xy} of the magnetoresistivity tensor at noninteger Landau-level filling factors ν in two-dimensional (2D) layers of charge carriers in semiconductor heterostructures in a magnetic field directed normal to the 2D layer. This effect was originally discovered at $Al_xGa_{1-x}As$-GaAs hetero-

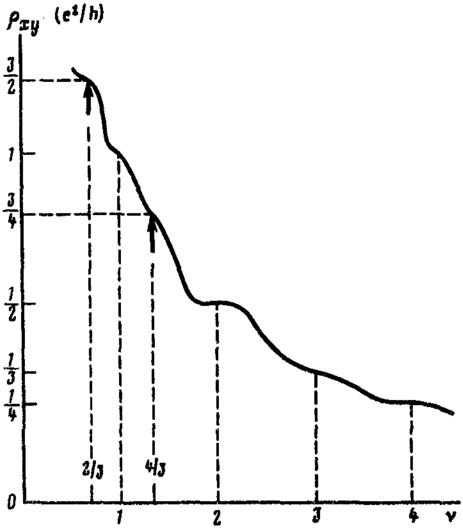

FIG. 1. Dependence of ρ_{xy} on the gate voltage V_g (and the Landau level filling factor ν) for sample A.

junctions,[1,2] and it has been studied most thoroughly in this case. In this case, structural features have been observed in ρ_{xx} and ρ_{xy} at $\nu = 2/7$, 1/3, 2/5, 3/5, 2/3, 4/5, 4/3, and 5/3. The nature of the effect remains puzzling, despite several theoretical attempts to explain it.

In this letter we report the observation of anomalies in the components ρ_{xx} and ρ_{xy} (at $\nu = 2/3$ and 4/3) of the resistivity tensor of a 2D carrier layer in metal-insulator-semiconductor structures on a silicon (100) surface.

In the experiments we used two samples with a maximum carrier mobility $\mu > 4\times10^4$ cm^2/(V·s) (measured at $T = 1$ K) in a magnetic field of 90 kOe at a temperature of 1 K. A current $J_x \simeq 2$ μA was passed through the sample, and the voltage between potential contacts—longitudinal contacts, V_x, and Hall contacts, V_y—was measured as a function of the voltage on the gate of the structure, V_g. At $V_g \lesssim 3$ V the current through the structure depended on V_g because of the nonideal current source and the high resistance of the regions near the source and drain contacts. This depen-

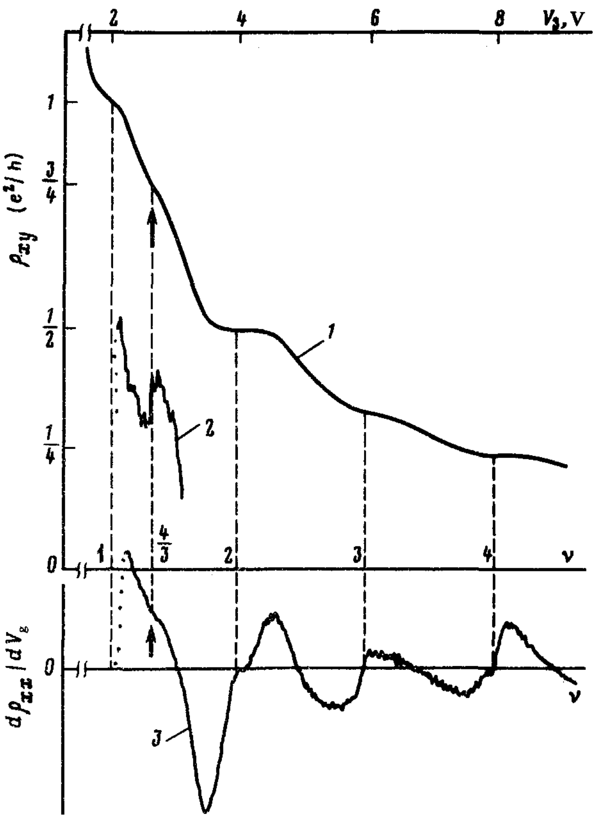

FIG. 2. For sample B: 1—Dependence of ρ_{xy} on the gate voltage and the carrier density; 2—32× magnification of the difference between ρ_{xy} and the average tangent to the $\rho_{xy}(\nu)$ curve near $\nu = 4/3$; 3—d_{xx}/dV_g (in arbitrary units) vs ν.

dence was taken into account in drawing the ordinate scale in the figures shown below; because of this dependence, the scale is not constant along the ordinate.

Figure 1 shows the Hall component of the resistivity tensor, $\rho_{xy} = V_y/J_x$, vs the carrier density in the 2D layer, n_s, according to the measurements for sample A. The density is expressed in units of the Landau-level filling factor $\nu = n_s/n_H$, where $n_H = He/(ch)$ is the density of sites at the Landau level. It can be seen from Fig. 1 that in addition to the plateaus near the integer values $\nu = 1,2,3,4$—which correspond to the "normal" Hall quantum effect—there are anomalies in ρ_{xy} at $\nu = 2/3$ and 4/3. The values of ρ_{xy} at these anomalous features are approximately equal to $h/[(2/3)e^2]$ and $h/[(4/3)e^2]$, respectively.

Figure 2 shows the corresponding dependence for sample B. We do not see an anomalous feature at $\nu = 2/3$ in this case, since the metallic-conductivity boundary of this sample lies near $\nu = 1$. The anomalous feature at $\nu = 4/3$ can be seen clearly on curve 2, which is a 32× magnification of the difference between the function $\rho_{xy}(\nu)$ and a straight line which approximates the average tangent to this function at the point $\nu = 4/3$. This anomalous feature can also be seen on the derivative $d\rho_{xx}/dV_g$ (curve 3). For both samples, the anomalous features disappear as the temperature is raised.

Observation of the fractional quantization of the Hall resistivity ρ_{xy} and of the corresponding anomalies in ρ_{xx} in silicon metal-insulator-semiconductor structures shows that this effect is apparently not peculiar to semiconductor heterostructures but is instead a universal property of 2D systems of charge carriers. A study of the details of this effect in a variety of systems will undoubtedly be helpful for reaching an understanding of the nature of this effect.

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