Point Contact Conductance in Backgated Heterostructures

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Recently, semiconductor mesoscopic systems have been drawn considerable interest from a viewpoint of carrier interaction in nanostructures. Carrier density is one of the most important factors in such systems and density-tunability is a useful means of understanding their transport characteristics. One of the fundamental structures of mesoscopic systems is a quantum point contact (QPC), and interesting carrier interaction, namely fractional quantized step, has been reported in QPCs by several groups [1-5]. In this paper, we discuss transport characteristics of density-tunable QPCs as an example of density-tunable mesoscopic systems.

The density-tunability of backgated heterostructure is based on a formation of two-dimensional electron gas (2DEG) in an undoped GaAs/AlGaAs heterostructure by the backside field effect. High mobility 2DEG with a wide electron density range has been attained in an undoped heterostructure [6]. Furthermore, the *frozen-surface* features of GaAs at low temperature make it possible to form high-quality 2DEG in a shallow position from the surface [7]. Therefore, a combination of arbitrarily shaped nanostructures on the surface makes a backgated heterostructure an ideal stage for density-tunable mesoscopic systems [8]. The formation of mesoscopic scale electron gas in an undoped heterostructure may enhance elecron-electron interaction less affected by the impurity effect.

The QPCs used in our study were fabricated by placing a split Schottky gate on the surface of a backgated heterostructure as shown in the inset of Fig. 1 [2,5]. The series of curves in the figure show conductance as a function of split-gate bias by changing the electron density by varying the backgate bias. Clear quantized steps can be seen over the whole range of the electron density. A fractional 0.7 anomaly can also be clearly observed in the figure. This anomaly becomes prominent with increasing temperature[1-5]. The step position and the clarity of the anomaly change as a function of electron density [2-5]. In particular, the step position decreases from 0.7 to 0.5 when electron density is decreased to less than 10^{11}cm^{-2} [2,3]. Transport characteristics in a magnetic field and other transport features of the backgated QPCs will also be discussed.

Experimental results suggest that the 0.7 feature could be explained by considering many particle phenomena including electron spin effects. There have been many theoretical proposals based on different mechanisms [9]. Although each of these theories succeeded to some degree in explaining the experimental results obtained, at present it is still difficult to explain all of the results satisfactory.

When a conventional modulation doped structure is grown on a backgated heterostructure, a density-tunable bilayer system is realized [10]. Use of these systems has made it possible to discover their intrinsic features [11]. Combining the spilt-Schottky gate of a bilayer system with backgate control has enabled the fabrication of a coupled QPC, where two closely-spaced QPCs are formed in top and bottom 2DEGs, respectively [12]. Although the coupled QPC can only be operated in a small voltage range due to the strong screening effect, mixing of the wavefunctions is evidenced in the strong coupling device.

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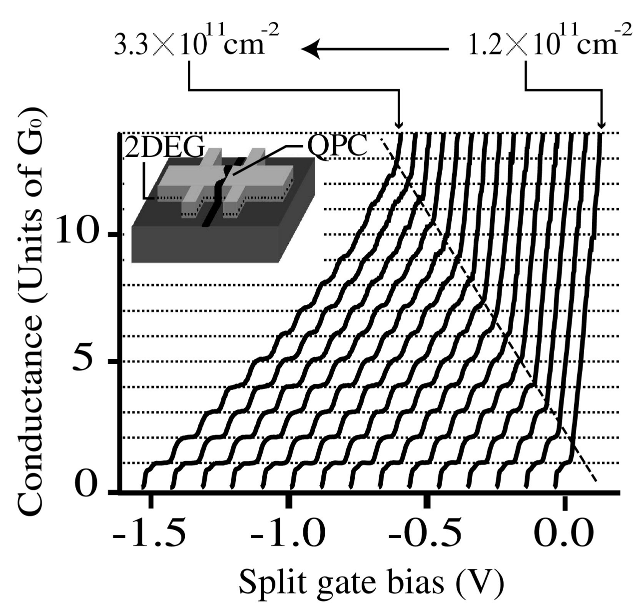

Fig. 1. Conductance characteristics of the backgated QPC measured at 100 mK. Conductance values are shown in units of $G_0(=2e^2/h)$. The elecron density of the 2DEG is varied from $3.3x10^{11}$cm^{-2} to $1.2x10^{11}$cm^{-2} with the backgate bias. The inset shows a schematic diagram of the backgated QPC.