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Multiple Negative Transconductances in an Indented Gate AlGaAs/GaAs Modulation Doped Field Effect Transistor

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Since the phases of the electron waves in a mesoscopic device are not averaged out, quantum interference phenomena appear in the electron transport. Conductance oscillations as a function of magnetic field due to the quantum interference have been observed in semiconductor heterostructures.[1] Also, various electrostatic quantum interference transistor structures in which the source-drain conductance can be largely controlled via the electron interference effect by the gate voltage have been proposed[2] and fabricated[3] with potential device applications. In this paper, we report multiple negative transconductances exhibited by an electron interference effect in the presence of a lateral modulaton of the gate potential in an indented gate AlGaAs/GaAs MODFET.

A narrow-wide-narrow(N-W-N) conducting channel of 2DEG AlGaAs/GaAs heterostructure with an indented gate was fabricated by means of electron beam lithography, chemical etching and lift-off techniques as shown in Fig. 1. The N-W-N channel was designed to increase a spatial coherence of the source and drain. The carrier concentration and mobility in this structure are deduced from the Hall measurement. We measured source-drain current(I_{ds}) as a function of the gate bias voltage(Vg) at 16mK by using of the lock-in technique.

When the size of an electronic device is comparable with the coherence length of electrons, the device is expected to show quantum mechanical electron interferences. We estimate the coherence length in this N-W-N transistor to be larger than 4.7 μm.[4] Source-drain current monotonically decreases in a normal gate transistor as the gate bias voltage negatively increases, even at low temperatures.[5] Contrary to the classical behavior, several oscillatory features appeared on the source-drain current of the indented gate N-W-N transistor(Fig. 2).

In order to verify the lateral quantum interference effect, we modelled two different paths of electron waves under the indented gate(Fig. 3). A sheet carrier concentration, n_s, varies by the gate voltage, and the Fermi-wavevector(k_f) of electron under the gate is accordingly changed, i.e., $k_f = (2\pi n_s)^{1/2}$ in 2-dimensional system. Therefore, the phase difference between the two different paths is $(k_f(V_g=0) - k_f(V_g))\Delta l$, where Δl is the path difference between the two paths, that is, 0.5 μm under the gate. The peaks of oscillotory I_{ds} occur when $(k_f(V_g=0) - k_f(V_g))\Delta l = 2m\pi$ (m is an integer). The number of oscillations until the source-drain current diminishes when the carriers totally depleted is estimated as follows: $m = k_f(V_g=0)\Delta l/2\pi \approx 10$. This estimated number of oscillations agrees well with that in the Fig. 2. Also, we show the transconductance(g_m) vs the gate voltage when V_{ds} (source-drain voltage) =10μV, i.e., $g_m = (\partial I_{ds}/\partial V_g)$, in Fig. 4. Negative transconductances are clearly seen in the regions of the negative slope in the sourece-drain current vs the gate bias voltage. This negative transconductance effect may be useful in device applications.

In conclusion, source-drain current measurements of the indented gate AlGaAs/GaAs MODFET provide multiple negative transconductances due to a lateral quantum interference effect.

<References>
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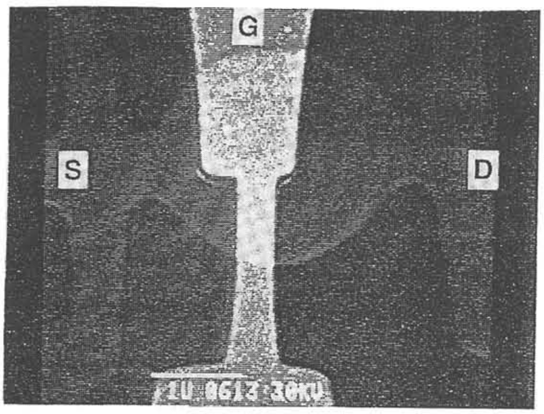

Fig. 1. Scanning electron micrograph of the indented gate N-W-N AlGaAs/GaAs MODFET.

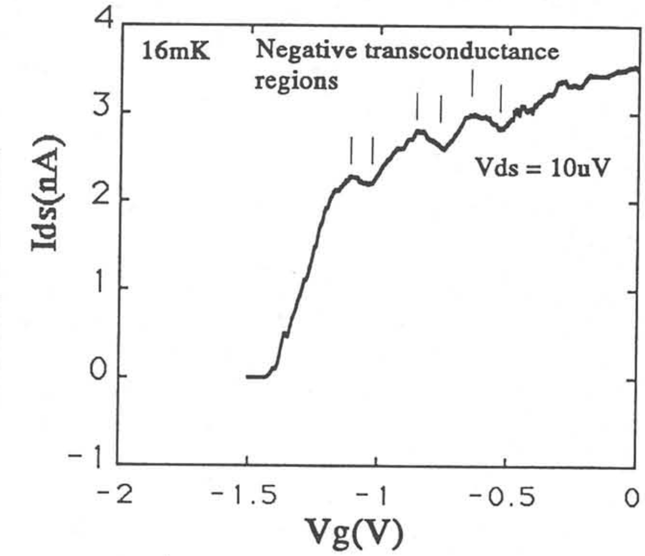

Fig. 2. Plot of the Ids vs Vg of the indented gate N-W-N AlGaAs/ GaAs MODFET.

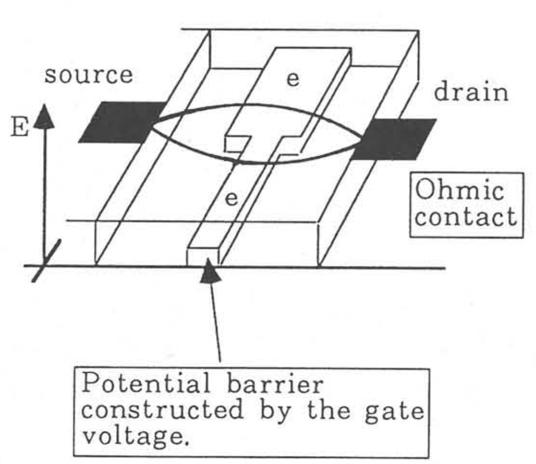

Fig. 3. Transport model of electrons. This device has two different paths between source and drain.

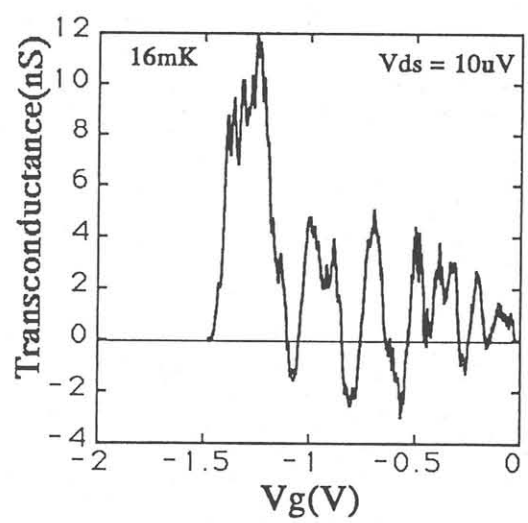

Fig. 4. Plot of the g_m vs V_g. This curve was calculated from the data in Fig. 2.