# Transport properties of a single pair of coupled self-assembled InAs quantum dots

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Artificial molecules have been realized using disk-shaped vertically coupled semiconductor quantum dots. Depending on strength of quantum mechanical coupling between the two dots, the artificial molecules have a “covalent” or “ionic” type bonding. The electron transports of the covalent and ionic type artificial molecule have been intensively studied so far [1, 2].

In this work, we incorporate vertically coupled two layers of self-assembled InAs quantum dots in the vertical dot configuration. This device allows us to study the electron transport through a *single pair* of coupled InAs dots. There are a number of studies on the optical properties of these InAs dots. In contrast, there are only a few works on the electron transport, though they can directly provide information about zero-dimensionality, interaction effects and interdot quantum mechanical coupling for electrons. Measurements of capacitance-voltage[3] and current-voltage[4] have been performed to investigate the electronic properties of InAs quantum dots, but the area density of self-assembled quantum dots is very high. Then, influence of inhomogenity is included in the obtained data.

We use a position sensitive gating technique[5] to measure a single pair of coupled InAs dots. We observe Coulomb oscillations associated with a single pair of coupled dots and find marked differences in the transport properties between the strongly and weakly coupled dots using samples with different thickness of the spacer layer between the InAs dots. The thickness of the spacer layer between the dots is 11.5 nm (material A) and 14.5 nm (material B). The prepared samples (sample A and B made from material A and B, respectively) have a cylindrical pillar structure. A 0.15 μm wide line mesa is attached to the pillar. The device structure is shown in Fig. 1. The transport through a single pair of the coupled dots is observed near the pinch-off point of the devices. Figures 2(a) and (b) show current vs. gate voltage ($V_G$) measured for sample A at 20 mK and sample B at 100 mK, respectively. For both samples, current oscillates corresponding to the one-by-one change of the number of the electrons (N) trapped in the dots. We find clear difference between the two samples in these figures: the current level is more or less same for all peaks in sample A, whereas, in sample B, it is not the case. Figure 3(a) shows a gray log-scale plot of *dI/dV* as a function of source-drain voltage ($V_{SD}$) and $V_G$ measured for sample A at 20 mK. The Coulomb oscillation in Fig. 2(a) is taken along the $V_{SD}$=0 V axis. Lots of well-formed Coulomb diamonds are observed. For $V_G < -0.7$ V, the dot is empty, i.e. N=0. Each diamond is closed along the $V_{SD}$=0 V axis. This indicates that the dots are in the quantum mechanically strong coupling regime. Figure 3(b) shows *dI/dV* data measured for sample B at 100 mK. The Coulomb oscillation in Fig. 2(b) is taken along the $V_{SD}$=0 V axis. Below a few well-formed Coulomb diamonds along the $V_{SD}$=0 V axis, kink structures indicated by the dotted lines are observed. A kink in the negative $V_{SD}$ and a vertical line in the positive $V_{SD}$ are always observed in pairs as indicated by the dot-dashed line. These features are quite different from those of the Coulomb diamonds in Fig. 3(a). The irregular features are due to that the dots are in the quantum mechanically weak coupling regime and electrons are localized in each dot. Similar results are previously observed for weakly coupled vertical dot system, made from a triple barrier structure, and well assigned to a small energy offset between the two dots [2]. By analyzing these structures, N is estimated to be six, trapped in only one of the two dots at $V_G$ = -0.85 V below the first well-formed Coulomb diamond. On the other hand, another dot is empty. In case more than one pair of the coupled dots contributed to the transport, the parallel conduction is proved by observation of two families of Coulomb diamonds.

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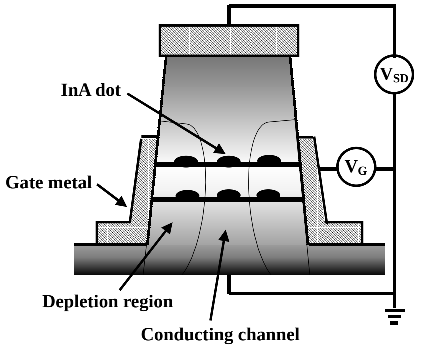

Figure1 Schematic illustration of cross-section of the single electron transistor used for the experiment. The geometrical diameter of the pillar is 0.35 µm (sample A) and 0.25 µm (sample B) and about one or two coupled dots (six) are present inside the pillar of the sample A (B)

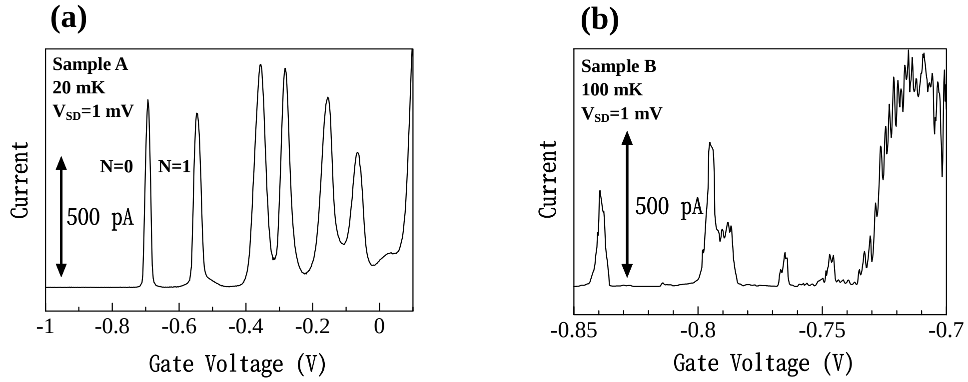

Figure2 Coulomb oscillations measured for sample A (a) at 20 mK and sample B (b) at 100 mK with $V_{SD}$= 1.0 mV.

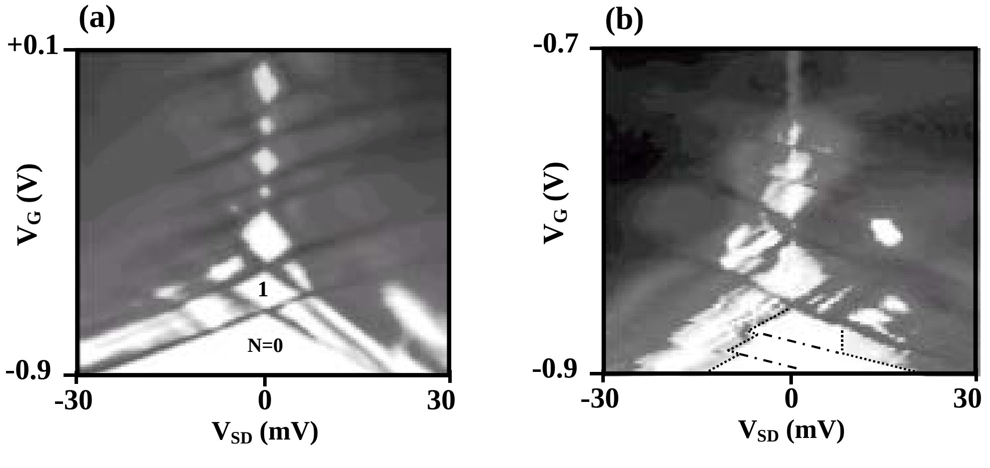

Figure3 Gray log-scale plot of *dI/dV* as a function of $V_{SD}$ and $V_G$, measured for sample A (a) at 20 mK and sample B (b) at 100 mK. Black region corresponds to higher conductance.