THz Rectification through a Single Metal Nanoparticle

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The nanogap electrode is a good experimental tool to study low-dimensional materials, such as single molecules (0D), carbon nanotubes (1D), and graphene (2D). By using nanogap electrode as an antenna to focus terahertz (THz) radiation onto the sample, we have observed ultrafast dynamic processes of molecules/atoms (e.g., molecular vibration[1]) and electrons (e.g., photon-assisted tunneling[2], intersublevel transitions[3]) at a sub-ps time scale. The magnitude of the THz electric fields in the nanogap determines what kind of mechanism takes place in the THz-induced single electron transport in the nanogap electrodes. However, the exact magnitude of the THz electric field is difficult to measure. Therefore, the purpose of this work is to develop a technique to exactly determine the THz electric fields within the nm-scale gap of the electrodes.

In this work, we have successfully obtained the THz voltage by measuring THz induced photocurrent in a single metal nanoparticle transistor. We used a single electron transistor (SET) structure that consisted of a single Au nanoparticle trapped in the nanogap metal electrodes as a sensitive THz detector and detected THz-induced photocurrent in the SET. Fig. 1(a) shows the Coulomb stability diagram of our sample. The two crossing patterns indicate that we captured a single metal particle in the nanogap. The THz signal of a single nanoparticle was obtained by measuring the THz-induced photocurrent in the SET sample. Fig. 1(b) shows the corresponding photocurrent distribution. The positive and negative photocurrent, which appears only nearby the boundaries of the Coulomb diamonds, demonstrates that the nonlinearity in tunneling conduction rectifies the THz field into a dc current. This process allows us to determine THz voltage difference across the gap by mapping the THz-induced photocurrent and the corresponding d^2I/dV^2, as shown in Fig. 1(c). Then, we can determine the exact THz E-field in the nanogap (V_{THz} = ~0.5 mV in this case), and even control the THz voltage in the SETs.

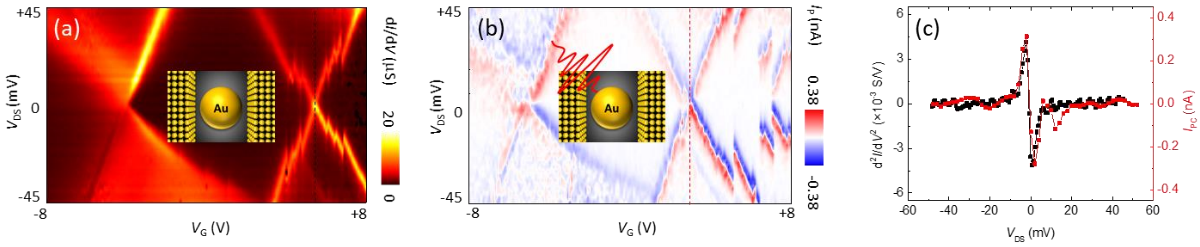

Figure 1 (a) Coulomb stability diagram of a single-Au particle transistor. **(b)** Color-coded photocurrents of the sample in (a). **(c)** The photocurrent (I_{PC}) and corresponding d^2I/dV^2 at the right Coulomb peak in (a)&(b).

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