Electrostatic Trapping and Measurements on DNA Oligomers and Graphitized Carbon Nanoparticles

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Electrical transport through mesoscopic conductors has been a major research area in the past two decades. Now the focus has shifted from artificially (lithographically) fabricated structures to ''natural'' mesoscopic systems such as molecules and nanoparticles. A variety of electronic devices based on single molecules, has been envisioned and some—realized experimentally.[1,2,3] Reproducible measurements on isolated molecules are still rare and typically involve a scanning probe microscope[1,4]. Fabrication of *compact* electronic nanodevices based on a single molecule remains the pivotal difficulty in molecular electronics. Nontraditional techniques have been applied for the fabrication of such devices.[5,6,7]

Here we present two examples of nanodevices fabricated using a new technique—electrostatic trapping. Two main types of devices will be discussed: (i) molecular junctions involving one or a few DNA oligomers connected to two Pt electrodes and (ii) all-metallic single-electron-tunneling transistors based on graphitized carbon nanoparticles.

In the first example, the results obtained by D. Porath et al.[8] on nanoscale devices involving two Pt electrodes linked by Poly(C)-Ply(G) DNA oligomers will be presented. Such periodic DNA sequence has been chosen in order to minimize the electron localization effects. The sample geometry and the principle of electrostatic trapping[7] are illustrated in Fig.1a. Two Pt electrodes (red) with a gap of only 8 nm between them (Fig.1b) were prepared by coating two free-standing SiN "fingers" (directed towards each other) with a thin Pt film. Practically, the smallest achievable spacing between the electrodes is 4nm.[7] The DNA is shown yellow in Fig.1a.

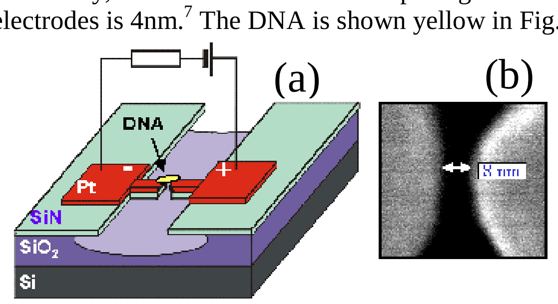

Fig. 1. (a) Schematic of the sample and illustration of the electrostatic trapping[7] principle. Two Pt electrodes (red) are linked with a DNA oligomers (yellow). (b) An SEM micrograph of the Pt electrodes (gray) separated with an 8 nm gap.

An example of a low-temperature transport measurement on DNA oligomers is show in Fig. 2. Measurements on our DNA-junctions strongly suggest that this 10 nm-long periodic DNA doublehelix is a large-band-gap semiconductor. Reproducible peaks on dI/dV vs. V curves (Fig.2) is associated with the band structure of the electrons delocalized along the DNA doublehelix. All curves are measured on the same sample.

Another example of a device fabricated by electrostatic trapping is the *oxide-free (all-metallic)* single-electron-tunneling (SET) transistor based on graphitized carbon nanoparticles (GCNP)[9] (Fig.3). Current vs. gate voltage measurements are presented in Fig.4. This measurements prove that GCNP are metallic and possess delocalized electronic states. The appearance of the period doubling (Fig.4) observed on one of the devices may be due to even-odd effects of the electronic filling factor. The offset charge noise of such *oxide-free* transistors will be compared to regular Al SET transistors (which operate at mK temperatures).

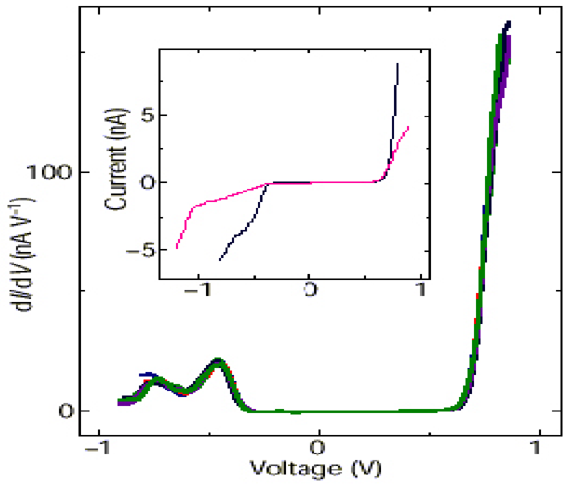

Fig.2. dI/dV curves measured on a DNA-junction device illustrated in Fig.1. The reproducible peak structure with a period of ~ 0.2 V is attributed to the current through the delocalized electronic bands of the DNA. The I-V curves measured at different times on the same sample are shown in the inset. (T = 100 K)

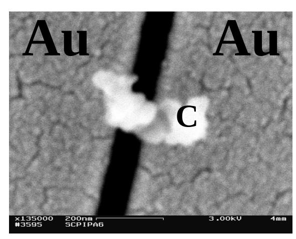

Fig.3. A scanning electron microscope (SEM) micrograph of a graphitized carbon particle (white) positioned over two Au electrodes separated by a 100 nm wide gap (black).

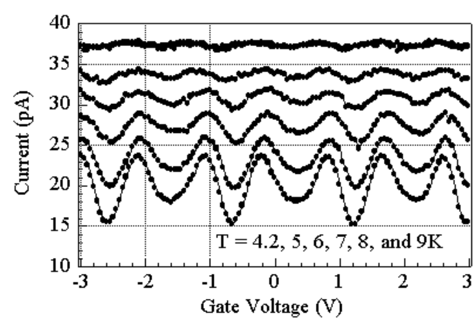

Fig.4. Current vs. gate voltage for the carbon single-electron-tunneling transistor. Different curves correspond to different temperatures with the lowest temperature of 4.2K represented by the bottom curve. The oscillation of the current is due to the SET effect.

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