Mysteries of persistent noise in single-wall carbon nanotubes

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Our experimental studies of 1/*f* noise in single wall metallic and semiconducting carbon nanotubes (M-SWNTs and S-SWNTs) reveal an extreme sensitivity of noise to the nanotube environment persisting much longer than vacuum induced changes in carbon nanotube conductivity.

Nanotubes were grown by thermal CVD on oxidized 100 nm Si conducting substrates and contacted with Ti/Au electrodes with 1 μm separation. Metallic and semiconducting nanotubes were randomly obtained during the growth.

Metallic nanotubes had linear and symmetrical current-voltage characteristics. Semiconducting nanotubes demonstrated non-linear, exponential current voltage characteristics typical for the Schottky contacts: $I \sim \exp(eV/3.5kT)$. Current in the semiconducting nanotubes at fixed voltage increased with the increase of the negative voltage applied to the substrate, indicating *p*-type conductivity.

The low frequency noise studies in all nanotubes followed $\sim 1/f$ and I^2 dependences on frequency, *f*, and current, *I*, respectively. Semiconducting nanotubes had three orders of magnitude higher noise level than metallic nanotubes. Since resistance of semiconducting nanotubes was dominated by the Schottky contacts, we assume that 1/*f* noise was originated from the contacts and/or from the part of the nanotube adjacent to the contacts.

In vacuum, noise decreased quickly (during the pumping out time of about a few tens of minutes) by over an order of magnitude for both metallic and semiconducting nanotubes. When the devices were restored to the atmospheric pressure, the resistance and noise levels were restored to the original values, however, the noise level took a much longer time to recover compared to the resistance. Several tens of hours were required to restore noise level to its original value in the atmosphere compared with several tens of minutes required to restore the initial value of the resistance.

High sensitivity of noise to the environment shows a potential for chemical sensor applications based on carbon nanotube noise characteristics.