Supporting information

Ultra Sensitive Mass Sensing with a Nanotube Electromechanical Resonator

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A. Fluctuations of the mechanical resonance frequency.

The mass resolution is given by the fluctuations of the mechanical resonance frequency σ_{f_0}. In our resonator σ_{f_0} is a consequence of the fluctuations of the mixing current $\sigma_{I_{mix}}$, as explained in the following. Figure 1 shows that $\sigma_{I_{mix}}$ remains similar for both on- and off-resonance frequencies. The standard deviation is $\sim$ 80 pA. On the resonance peak, the slope of $I_{mix}(f)$ is finite and fluctuations of I_{mix} lead to fluctuations in the measurement of f_0. Using the 10 pA/kHz slope indicated by the arrow in Figure 1, we obtain 8 kHz, which is close to 15 kHz measured for the standard deviation of f_0.

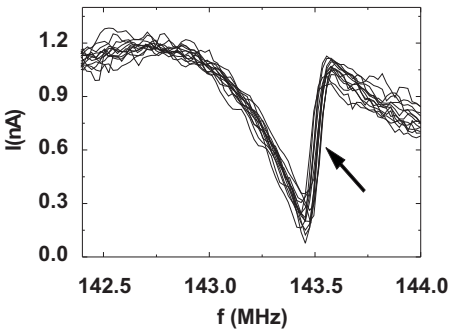

FIG. 1: Scans of I_{mix} as a function of the actuation frequency for device C at 5K. 25 successive scans are recorded. The arrow indicates the steepest slope, $\sim$ 10 pA/kHz.

The fluctuations of I_{mix} are likely caused by the random motion of nearby charge fluctuators, which are known to generate an important $1/f$ noise in nanotubes [1]. This is illustrated in Figure 2 for another nanotube resonator. I_{mix} jumps between different values, which can be understood as one (or a few) charge fluctuators that fluctuates back and forth between different states. Since this motion is a stochastic process, it can happen that these I_{mix} jumps stop during a certain period of time, as observed in Figure 2a. This is also observed during certain time windows in the Figure 4b of the paper. Interestingly, the mass resolution gets significantly enhanced.

We are pursuing our effort to further reduce this charge noise. A nanotube resonator has been fabricated for which

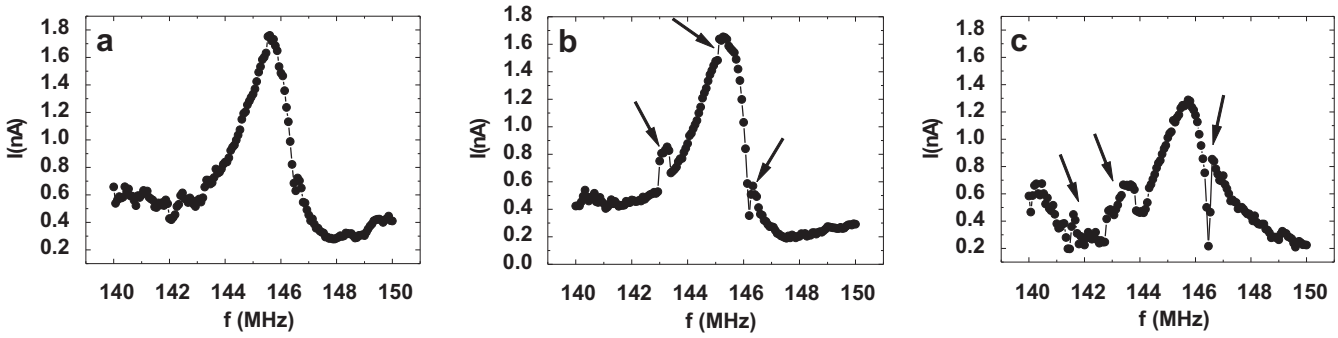

FIG. 2: Scans of the mixing current as a function of the frequency at 20 K for device D. I_{mix} fluctuates differently for the three scans. (a) Absence of large I_{mix} jumps. (b) A few I_{mix} jumps. (c) Many I_{mix} jumps. The arrows indicate some of the jumps.

σ_{f_0} is 1.8 kHz. However the mass responsivity has not been measured.

B. Evaporation of chromium.

An important issue for the determination of the mass responsivity $\Re$ is to determine how many atoms are evaporated onto the nanotube resonator. For this, we evaporated chromium for 2 minutes on a structure patterned in PMMA and its thickness was measured to be 1.2 nm with an atomic force microscope. Since the evaporation time for the measure of $\Re$ is much shorter (1.5 s), we have to ensure that the evaporation rate does not change with time due to, e.g., the temperature inertia of the evaporator. Figure 3 shows that the nominal thickness measured with the quartz crystal is linear in time, suggesting that the evaporation rate remains constant.

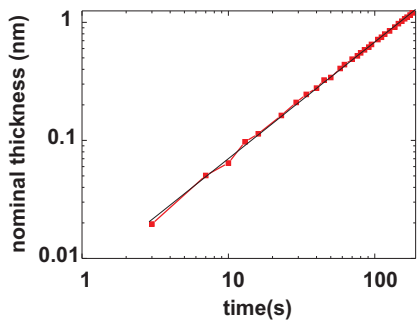

FIG. 3: Thickness measured with the quartz crystal as a function of time. The black line is a linear fit. The slope is 1 showing that the thickness increases linearly with time.

[1] Tobias, D.; Ishigami, M.; Tselev, A.; Barbara, P.; Williams, E. D.; Lobb, C. J.; Fuhrer, M. S. *Phys. Rev. B.* **2008**, *77*, 033407.