**Carbon Nanotubes: from Powders to Tunable Resonators**

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**Introduction:** Carbon nanotubes (CNTs) are promising candidates for nano-electro-mechanical systems (NEMS). We report large-scale fabrication of resonant-body CNT field-effect transistors with an integration density of $\approx 10^9$/cm$^2$, a yield of $\approx 80\%$ and nanoprecision. Electrical actuation/detection and novel in-situ upward/downward resonance frequency tuning are reported. The CNT resonators offer promising features for both radio-frequency and ultra-high resolution sensing applications.

**CNT Powders to Solution** is prepared by sonicating CNTs in aqueous media.

**Large-scale Precise Assembly** of the individually accessible CNT resonators is depicted.

**Simultaneous Fabrication!**

- PMMA
- LOR
- PMMA
- LOR
- PMMA

**Precise Assembly!**

A yield of $\approx 80\%$ and a density of $10^9$/cm$^2$ have been achieved with nano-precision; $\sim$ Current NEMS integration complexity

**Hysteresis-free Behavior** of CNT-FETs can be influenced by chemical/thermal treatments.

Chemical/thermal treatments influence contamination amount $\rightarrow$ gate hysteresis.

**RF Characterization** of a typical CNT resonator was performed.

Mass sensitivity $\sim 80$ zg

A resonant frequency $f_0 \sim 220$ MHz and a quality factor of $Q \sim 80$ have been observed.

**Novel In-situ Frequency Tuning** benefits from dual-gate configuration.

**Downward Tuning**

**Upward Tuning**

When the lateral gate or the lateral gate is biased, $f_0$ shifts accordingly.

**Summary:** We report, for the first time, large-scale precisely assembled CNT resonators without hysteresis. Resonant frequency can be tuned upwards/downwards. These results enable future application of CNT-based NEMS devices, such as ultra-sensitive mass sensors.

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**Publications:**