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Carbon Nanotubes: from Powders to Tunable Resonators

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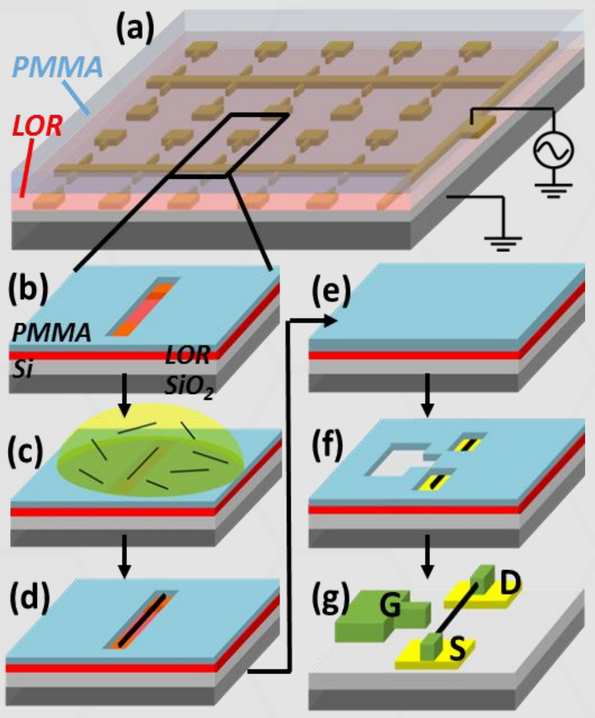
Introduction: Carbon nanotubes (CNTs) are promising candidates for nano-electro-mechanical systems (NEMS). We report large-scale fabrication of resonant-body CNT field-effect transistors with an integration density of >10^6/cm^2, a yield of ~ 80% and nanoprecision. Electrical actuation/detection and 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.

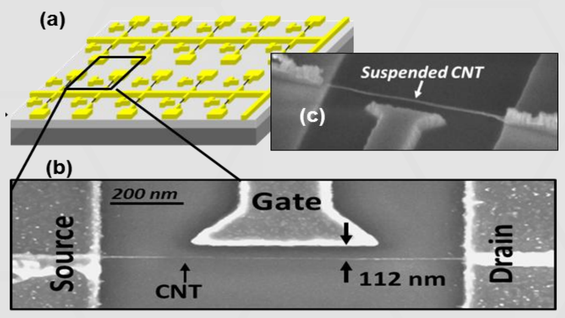
Large-scale Precise Assembly of the individually accessible CNT resonators is depicted.

Simultaneous Fabrication!



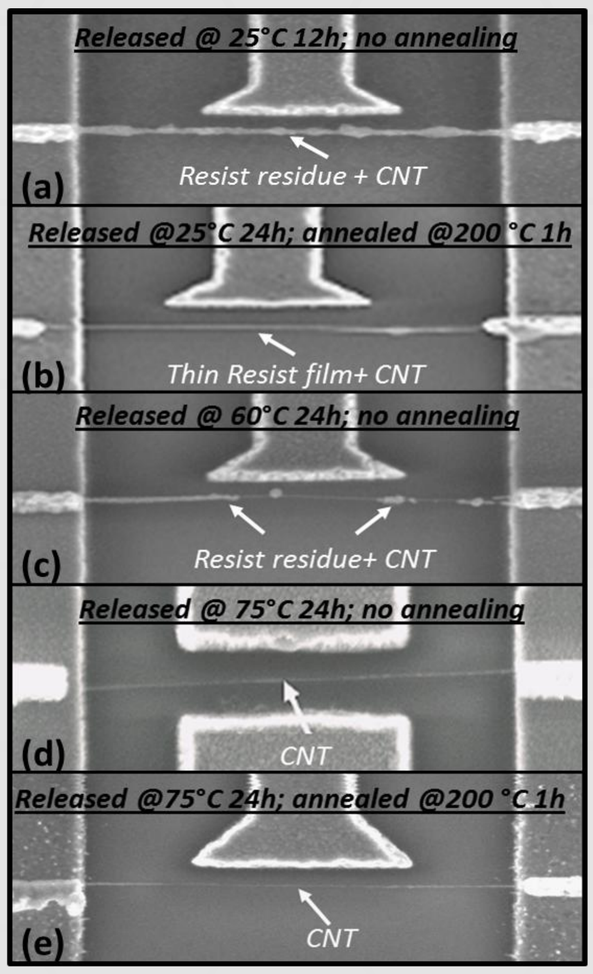
Precise Assembly!

SiO_2 Si LOR PMMA Ti/Pd CNT

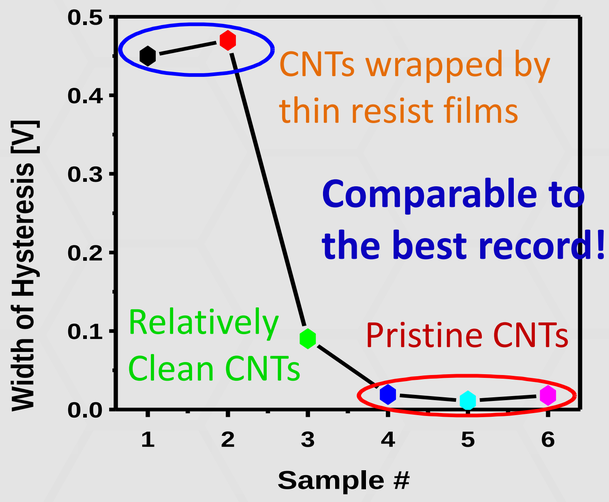


A yield of ~ 80% and a density of 10^8/cm^2 have been achieved with nano-precision;
~ Current NEMS integration complexity

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

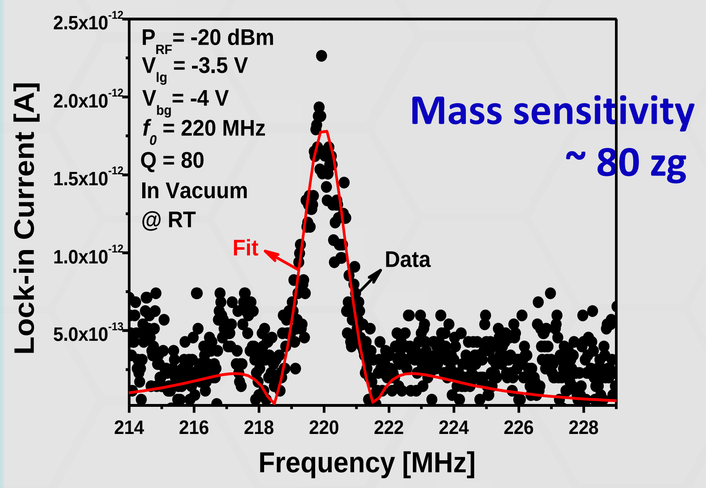


Chemical/thermal treatments influence contamination amount➔gate hysteresis.



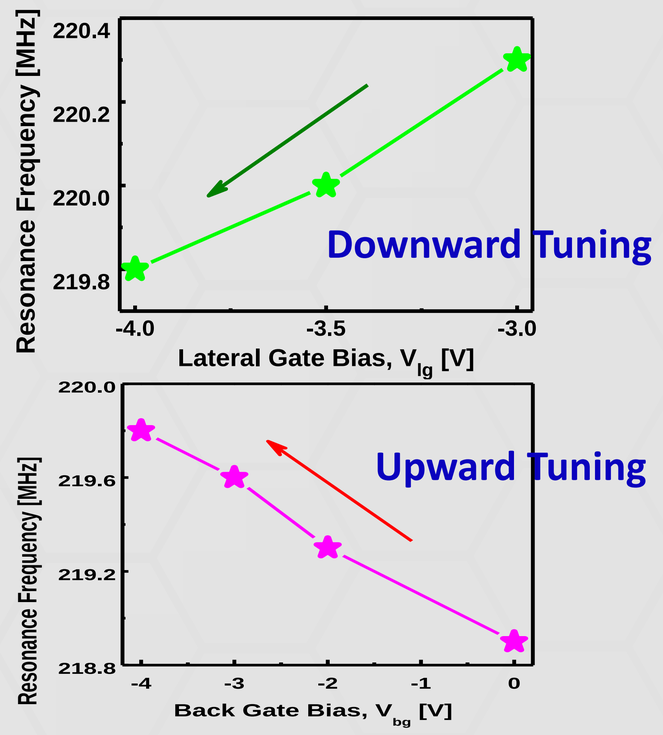
Gate hysteresis has been minimized down to ~ 13 mV, which is negligible.

RF Characterization of a typical CNT resonator was performed.



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

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



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:

1. J. Cao, S. Bartsch, A. M. Ionescu, IEDM 2012.
2. J. Cao, A. M. Ionescu, Carbon, 2012.
3. J. Cao, A. M. Ionescu, APL, 2012. *More upon request*

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

EMPA Materials Science & Technology

CabTuRes Carbon nanoTube Resonators