**Single wall carbon nanotubes as highly sensitive nano-electromechanical hybrid systems: driving, braking, detection**

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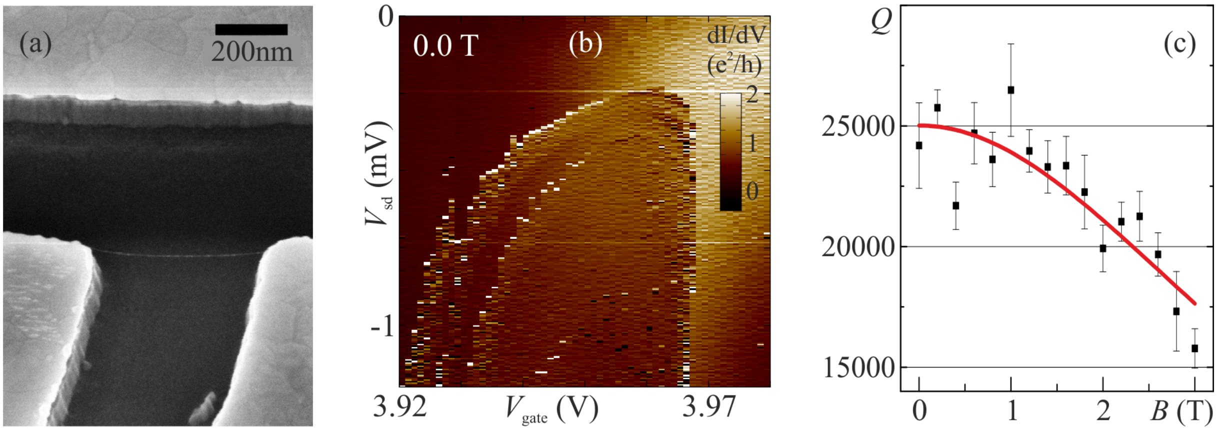
## Abstract

Single wall carbon nanotubes are not only excellent electrical conductors or semiconductors. Edges with dangling bonds, which could lead to unpredictable electronic behaviour, are intrinsically absent because of the closed tube structure. The nanotubes can be grown defect-free at considerable lengths, and are chemically stable. Additionally, the bonds of the carbon lattice cause large mechanical stability, with a Young's modulus significantly exceeding that of stainless steel.
Recent research has shown the mechanical quality factor of a suspended carbon nanotube nano-electromechanical resonator to rise above $Q \sim 10^5$ at cryogenic temperatures [1]. At these high values, mechanical motion can be excited by minute driving forces. At the same time, the electronically nonlinear behaviour of the quantum dot forming inside the carbon nanotube enables detection of the mechanical motion.
With this, we present a rich system where single-electron tunneling directly couples to and influences mechanical motion [2,3]. A dc current alone is sufficient to excite vibration via feedback effects [2-4]. In turn, the mechanical vibrations can be suppressed with a magnetic field [4] by means of eddy current dissipation. The interaction between mechanical and electronic system can be directly used for sensing applications; the quantum dot provides a clean few-carrier system. As a perspective, future experiments may show a carbon nanotube as a system mesoscopic or quantum mechanically coherent in both electronic and mechanical aspects.

## References

[1] A. K. Hüttel, G. A. Steele, B. Witkamp, M. Poot, L. P. Kouwenhoven, and H. S. J. van der Zant, *“Carbon nanotubes as ultra-high quality factor mechanical resonators”*, Nano Letters **9** (2009), 2547.
[2] G. A. Steele, A. K. Hüttel, B. Witkamp, M. Poot, H. B. Meerwaldt, L. P. Kouwenhoven, and H. S. J. van der Zant, *“Strong coupling between single-electron tunneling and nanomechanical motion”*, Science **325** (2009), 1103.
[3] A. K. Hüttel, H. B. Meerwaldt, G. A. Steele, M. Poot, B. Witkamp, L. P. Kouwenhoven, and H. S. J. van der Zant, *“Single electron tunneling through high-Q single-wall carbon nanotube NEMS resonators”*, physica status solidi (b) **247** (2010), 2974.
[4] D. R. Schmid, P. L. Stiller, Ch. Strunk, and A. K. Hüttel, *“Magnetic damping of a carbon nanotube NEMS resonator”*, New Journal of Physics (accepted), arXiv:1203.2319 (2012).

**Figures**




(a) Scanning electron micrograph of a suspended, ultra-clean carbon nanotube lying across a trench between metallic contacts. (b) Abrupt switching effects in the differential conductance of the embedded quantum dot, caused by mechanical feedback. (c) Electromechanical damping in an externally applied magnetic field.