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Embedded MEMS actuators for CNT straining tests

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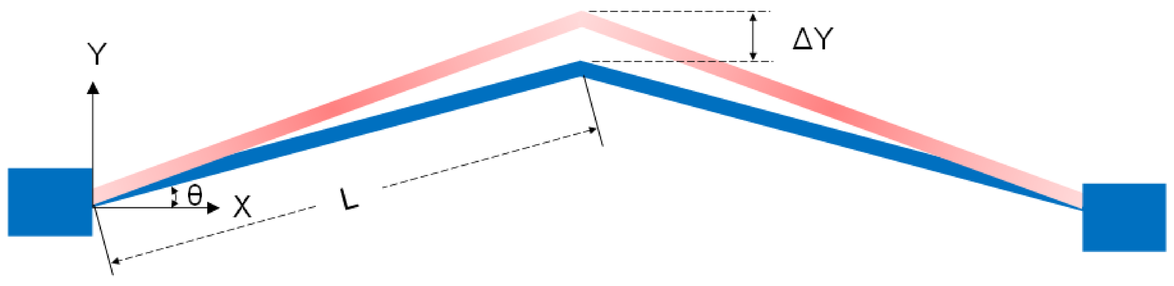
Abstract

We present an approach for straining CNTs, employing an embedded MEMS actuator, that is different and less disruptive than previous methods, such as ATM indentation. For the first time, we report on the electromechanical response −including tensile loading and transport measurements− of suspended CNTs strained by a MEMS actuator, which is fabricated by an integrated CNT-MEMS process flow.

MEMS actuator design

To lower the driving voltage of the strain test, we choose bent-beam electro-thermal actuators. The free-displacement is determined by the dimensions of the beams as well as the temperature difference, as described by the formula below [1].



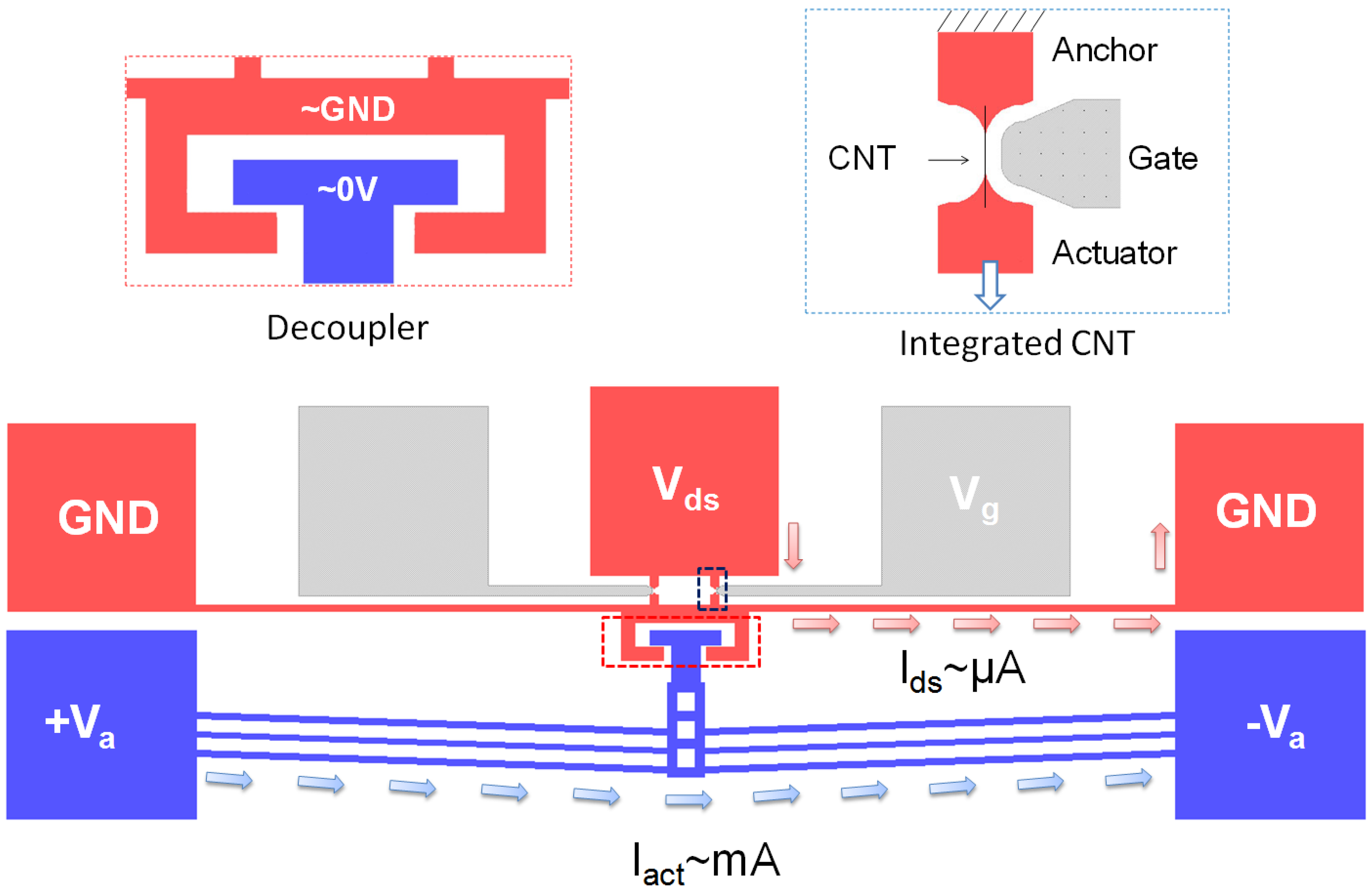
$$\Delta Y = \alpha \cdot \Delta T \cdot L \cdot \frac{\sin\theta}{\sin^2\theta + \cos^2\theta \cdot \left(\frac{12\,I}{A \cdot l^2}\right)}$$

Dimensions:

- Width= 2μm
- Length= 325μm
- Thickness= 4 μm
- Angle= 1°
- ρ_{Si}= 0.01 Ω-cm
- Voltage=+/- 2.5V

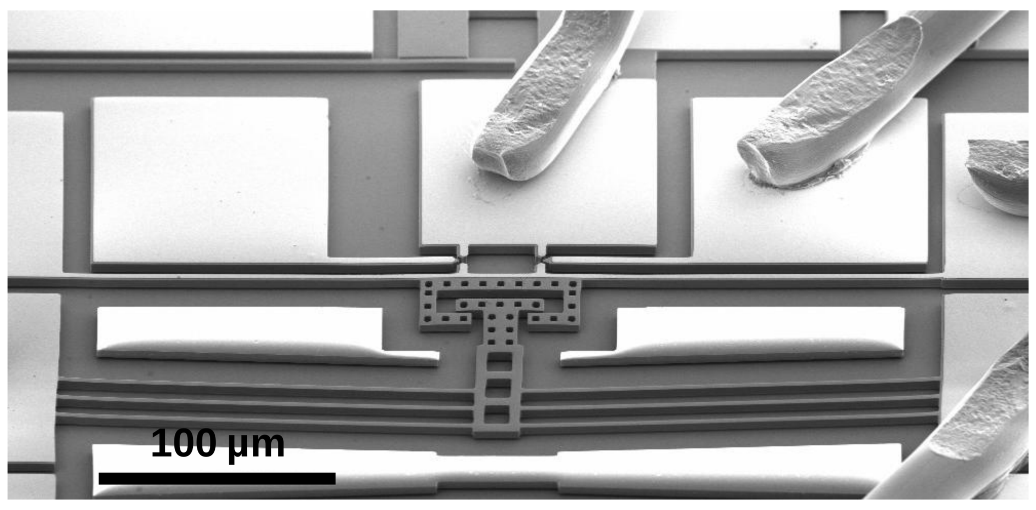
Working mechanism

By our developed integration process [2], a suspended CNT can be integrated onto Si tips, as shown in the figure below. When the displacement of the actuator exceeds the gap in the current-decoupler, the CNT under test is strained.

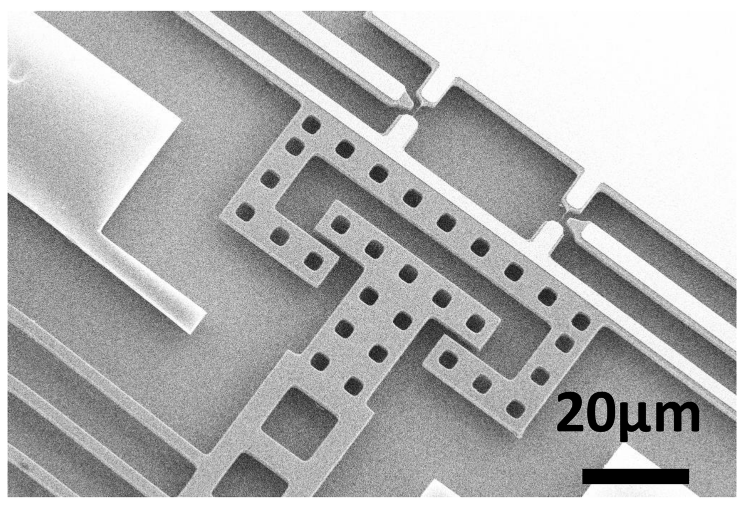


To measure the current through the CNT (I_{ds}), a current-decoupler is designed to insulate I_{ds} from actuator current, I_{act}. By symmetric biasing and the native oxide on the sidewalls of the decoupler, these two currents can be separated.

Fabrication results

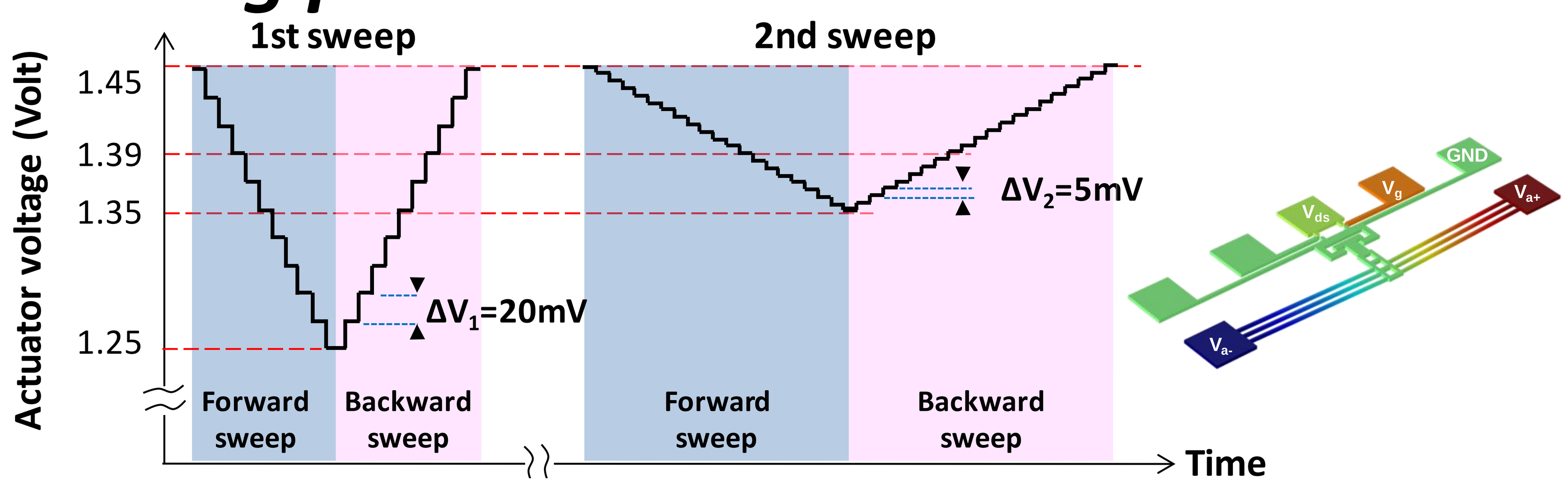


SEM tilt view of the device



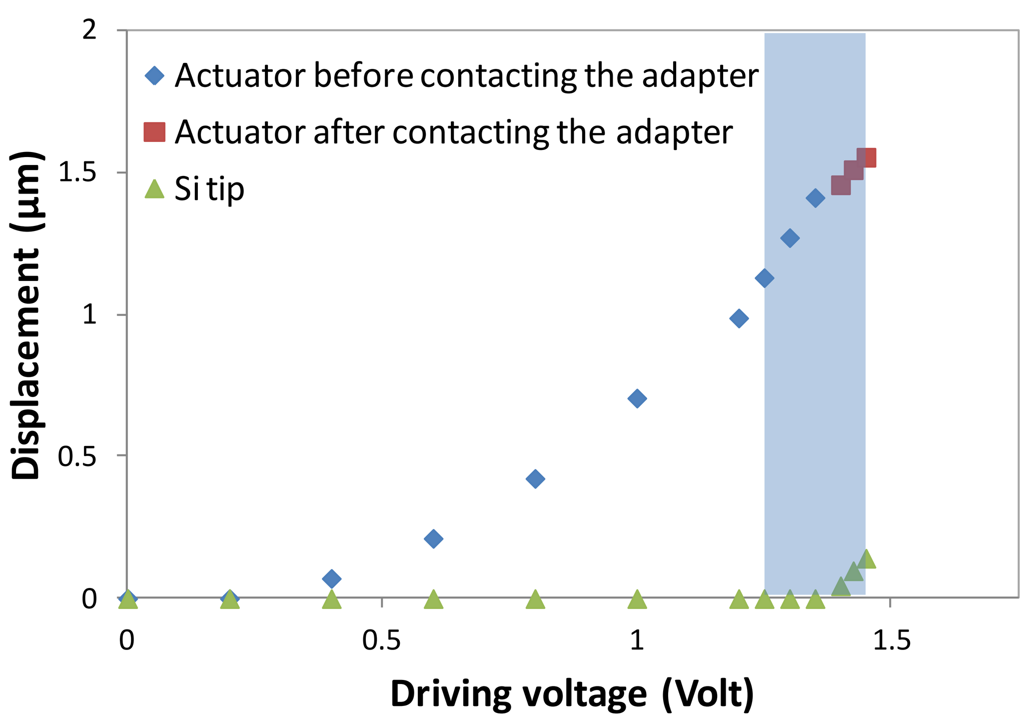
Close-up of the decoupler

Testing protocol

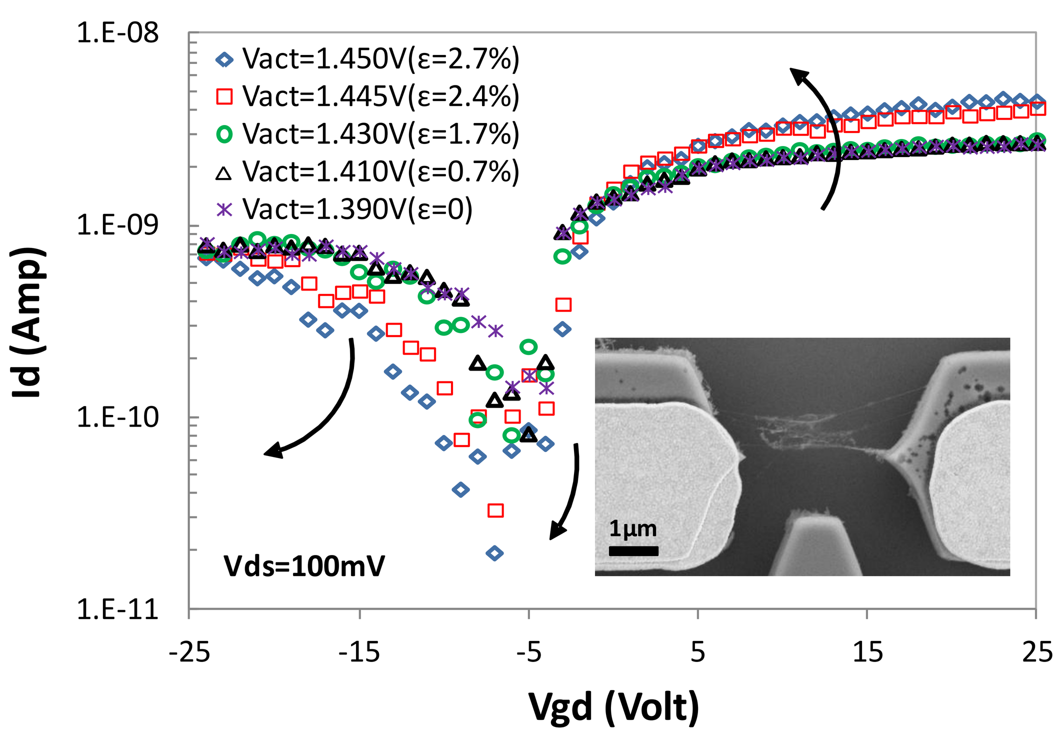


Driving voltage sweep for electro-mechanical characterization

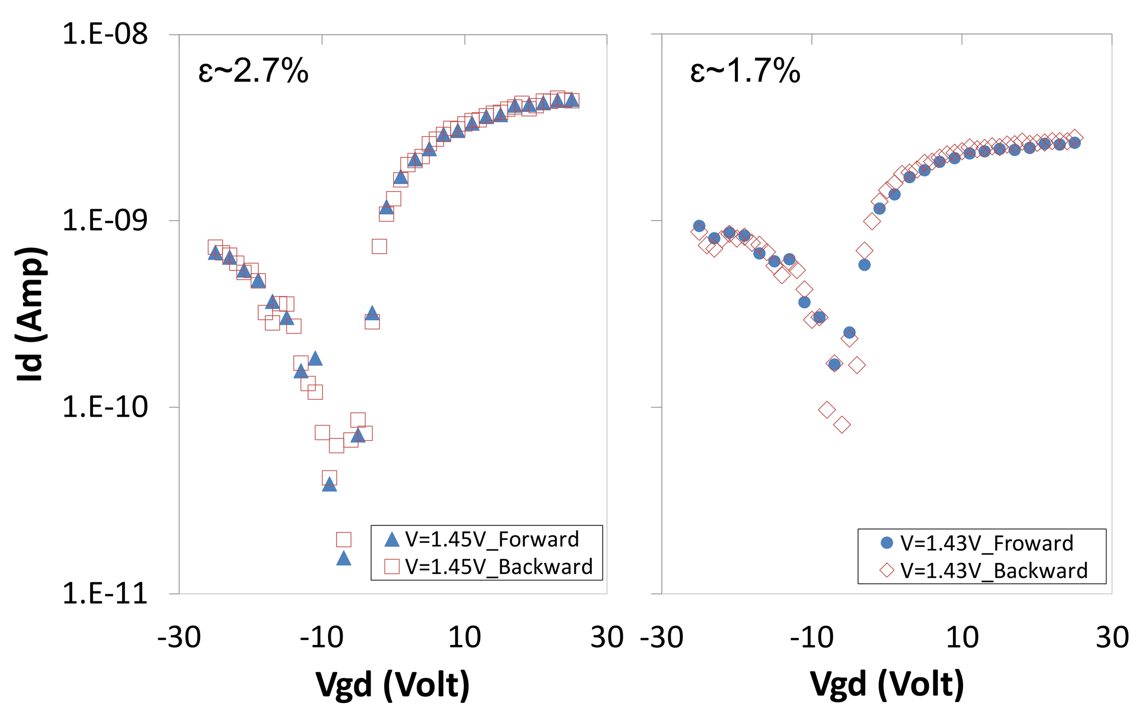
Strain tests of CNTs



Characterization of a MEMS actuator.



Transport measurements at different driving voltages. Inset shows an SEM image of the device under test.



Reproducibility of transport measurements at two different strains.

Acknowledgements

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Reference

[1] Y. Zhu, et al., *J. Micromech. Microeng. 16 (2006) 242–253*

[2] S.-W. Lee, et al., *Proc. IEEE NEMS 2011, pp. 37-40*

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