Chirality effect on the motion between MWNT shells

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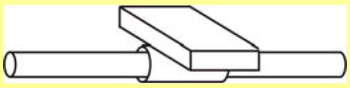
Motivation & background

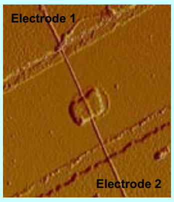
- In MWNTs, the intershell friction is ultra-low
- Actuation has been demonstrated using
  - electrostatic interaction [1, 2]
  - AFM [3]
- Friction due to impurities [1 - 3]



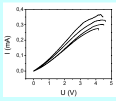
Results

- Actuation with a current through the MWNT
- Rotational or translational motion
- Friction at the ultimate limit (shell-shell interaction)

Nanofabrication

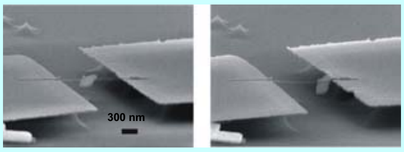


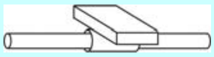
- Shells are locally removed [4 - 6]



- Structure is released with HF

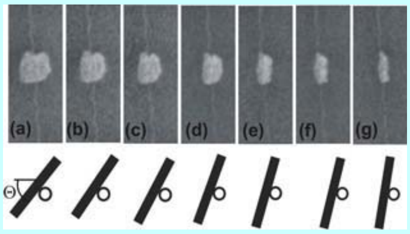
Device characterisation



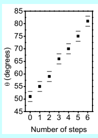


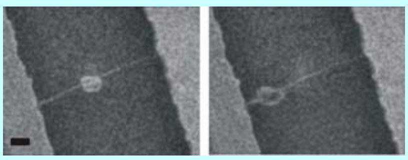
Verification of the device layout by moving the plate with an AFM tip

Rotation or translation of plate by passing a large current



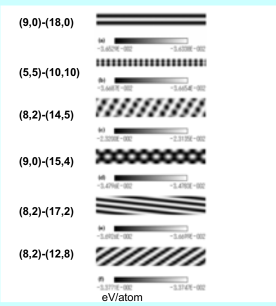
- Stepwise rotation
- Rotation of ~5º (0.7 nm)





- Translation

Potential barrier to the motion between two shells

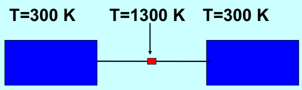


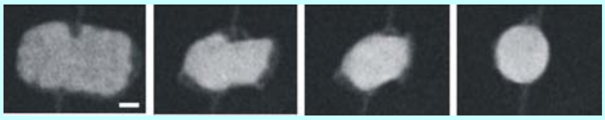
Calculations by Saito et al. [7]

- Rotation or translation (depending on chiralities)
- Periodic barrier
- Barrier energy ~10 μeV/atom

n = Planck distribution
v = velocity of the phonons

The plate is very hot





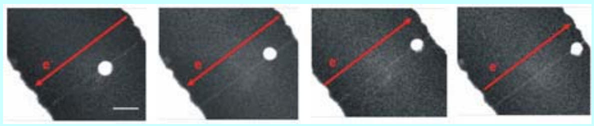
- $$\Gamma = \frac{\omega}{2\pi} e^{-\frac{\Delta E}{k_B \cdot T}}$$

diffusion rate $\Gamma \sim 1$ Hz, $\omega = (k/m)^{1/2}$, $k \approx \Delta E/a_0$, $a_0 = 1$ nm, m mass of gold plate

- Diffusion barrier $\Delta E \sim 17$ μeV/atom

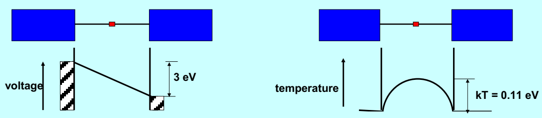
Good agreement with calculations of Saito et al. ☺

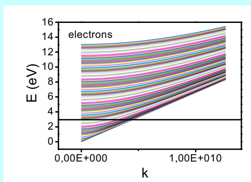
Current reversal



Same direction of motion upon current reversal

Electrons vs phonons

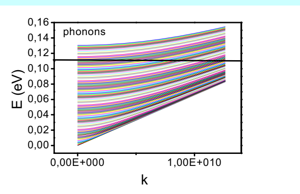




Estimated number of electrons

~ 2 · 10^{14} (1/s)

(One shell carries 20 – 40 µA)



Estimated number of phonons

~ 4 · 10^{15} (1/s)

$I = \sum nv$

n = Planck distribution
v = velocity of the phonons

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[1] A. M. Fennimore, T. D. Yuzvinsky, Wei-Qiang Han, M. S. Fuhrer, J. Cumings, A. Zettl, Nature (London) 424 (2003) 408.
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