MECHANICAL PROPERTIES AND ANISOTROPY OF CARBON NANOTUBES AND BIOLOGICAL MICROTUBULES

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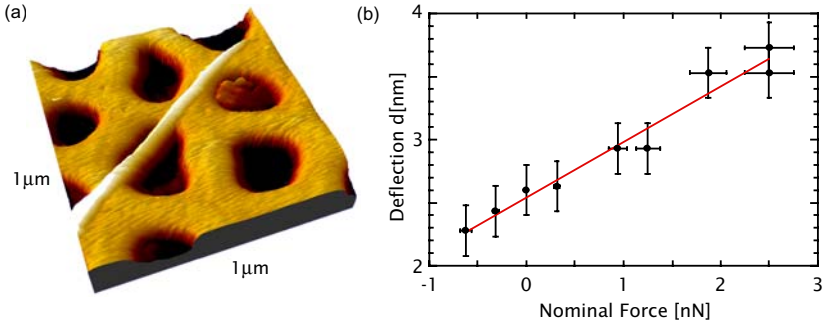
High elastic modulus of carbon nanotubes is frequently assumed as granted, being close to that of diamond (~ 1000 GPa). Using our AFM-based "Swiss cheese" method [1], we measured several families of carbon nanotubs (CNT's): multi-wall, double-wall and single-wall CNT's, produced by several European laboratories using different processes.

Multi-wall CNTs obtained using arc-discharge method have perfect structure and high Young modulus. However, multi-wall tubes synthesized using chemical vapour deposition (CVD) have always deceivingly low modulus, below 100 GPa. High temperature annealing (up to 2400 C), doesn't improve Young's modulus. We find, on the other hand, that CVD grown double-wall CNTs can have high modulus, close to 1 TPa. They seem to be the most promising CVD-tubes for nanomechanical applications.

Single-wall CNTs preferentially assemble into ropes, where inter-tube binding is ensured by weak Van der Waals forces. Such ropes are very flexible, what limits seriously field of applications. Using well chosen irradiation energy of electrons we could introduce covalent links between individual tubes, obtaining mechanical properties close to theoretical predictions [2].

The same "Swiss cheese" method was applied to measure elastic properties of microtubules in liquid as a function of temperature [3]. Finally, usage of the nanomanipulator as a measuring tool will be mentioned.



a) AFM Image of single-wall nanotube bundle lying on porous alumina filter
b) Measured dependence of vertical deflection on the applied nominal force
results from EPFL thesis No. 2876 of Andras Kis, see also: http://nanotubes.epfl.ch

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[3] A. Kis, S. Kasas, B. Babic, A. J. Kulik, W. Benoît, G. A. D. Briggs, C. Schönenberger, S. Catsicas, and L. Forró, Phys. Rev. Lett. **89** (2002) 248101.