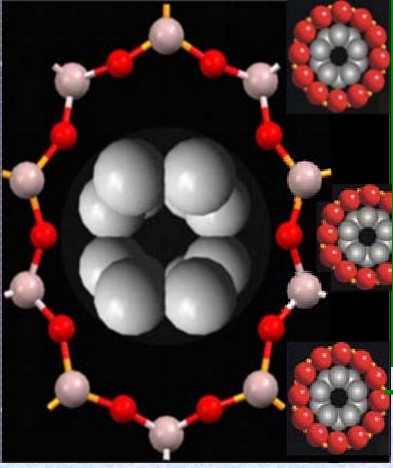

New World Record
Ø0.3nm Single-Walled Carbon Nanotubes ––– the tiniest in the World

Milestone in Carbon Nanotube Research:

2000: Fabricated world's record small single-walled carbon nanotubes with diameter of only 0.4nm.
Nature **408**, 50 (2000)

2001: Discovery of superconductivity from the 0.4nm SWNTs, for the first time, demonstrated superconducting behavior from a pure carbon structure.
Science **292**, 2462 (2001)

2004: Observation of novel optical properties in 0.4nm SWNTs.
Phys. Rev. Lett. **87**, 127401 (2001);
Phys. Rev. Lett. **93**, 017402 (2004)

2008: New world record in the tiniest SWNTs, fabricated 0.3nm SWNTs.
Phys. Rev. Lett. **101**, 074402 (2008)

2009: Superconductivity mechanism of the 0.4 nm SWNTs array was revealed.
PNAS **106**, 7209 (2009)

Research Group:

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Ultra thin SWNTs — beyond their structural stability

Small-diameter single-walled carbon nanotubes (SWNTs) are of particular interest with expectation of clearer quantum effects. With decrease of the tube diameter, however, the strong curvature effect leads to a dramatic increase of elastic energy, which eventually makes a free-standing SWNT unstable. Theoretical simulations indicated that free-standing SWNTs with a diameter of 0.4 nm are already at the botom edge of stability.

In 2000, Prof. Zikang Tang and his colleagues succeeded to fabricate the world's smallest SWNTs with a diameter of only 0.4nm. These tiny SWNTs are strictly aligned in the nano-channels of a zeolite single crystal. The spatial confinement of the

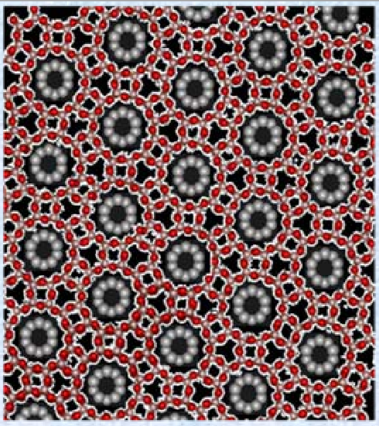

Fig. 1. 0.4nm SWNTs array in the channels of zeolite AFI single crystal, viewed along (001) direction.

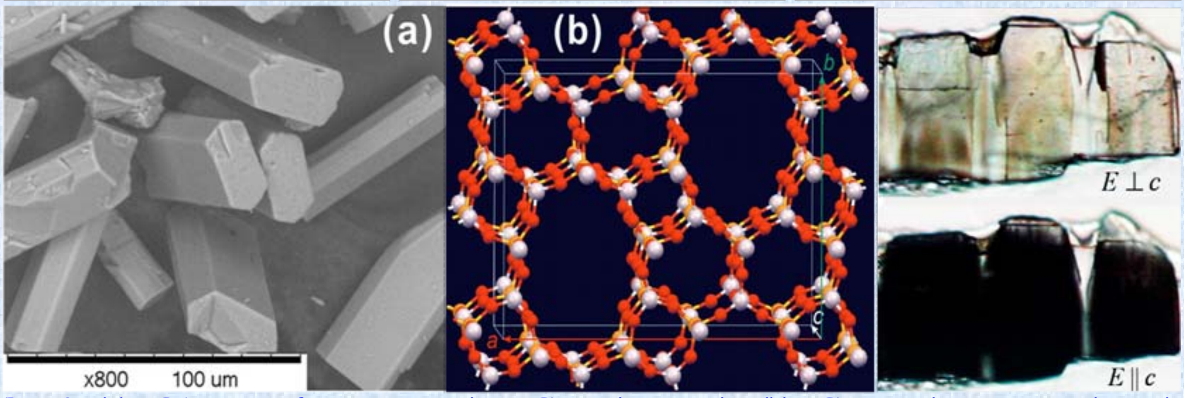

Fig. 2. (a) SEM image of as-grown zeolite AEL single crystals. (b) AEL crystal structure. The red spheres represent oxygen atoms and the grayish spheres denote Al or P atoms. (c) Optical microscope image of the AEL crystals with SWNTs viewed for light polarized perpendicular ($E \perp c$) and parallel ($E \parallel c$) to the tube direction.

channel wall is crucial in stabilizing the marginally stable tube structure. In 2001, they discovered novel one-dimensional superconducting fluctuations in the 0.4nm SWNTs — the first time demonstration of superconducting behavior from a pure carbon structure. The superconducting mechanism of the 0.4nm SWNTs has been recently revealed: weak coupling between SWNTs in the nanotube array plays a key role in their novel superconductivity properties.

The research group has recently broken their own world record by making even smaller SWNTs using a new kind of zeolite AEL single crystal as the template (Fig. 2a). The AEL single crystal has parallel arrayed elliptical channels with cross-section dimension of 0.6nm x 0.9 nm (Fig. 2b). SWNTs in the elliptical nano channels are of zigzag (2,2) chirality, which is the only possible structure for the 0.3nm SWNT.

Switch between metal and semiconductor

It is interesting that the (2,2) SWNT has two metastable ground states corresponding to two slightly different lattice constants in the axial direction, one state is metallic and the other is semiconducting (Fig. 3).

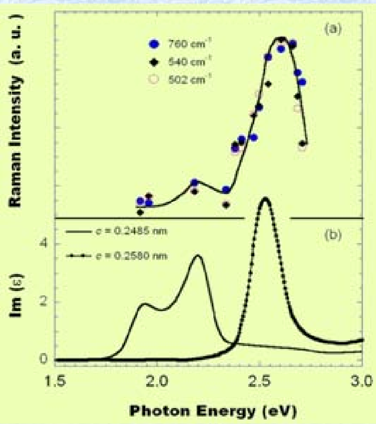

Fig. 3. (a) Resonant Raman excitation spectra of the 0.3 nm SWNTs. (b) The calculated dielectric functions of the (2,2) carbon nanotube corresponding to the metallic state (c = 2.48Å, solid line) and semiconducting state (c = 2.58Å, dot chain), respectively.