Carbon nanotubes

T. W. Ebbesen, Cones and Tubes: Geometry in the Chemistry of Carbon, *Acc. Chem. Res.* **31** (1998) 558.

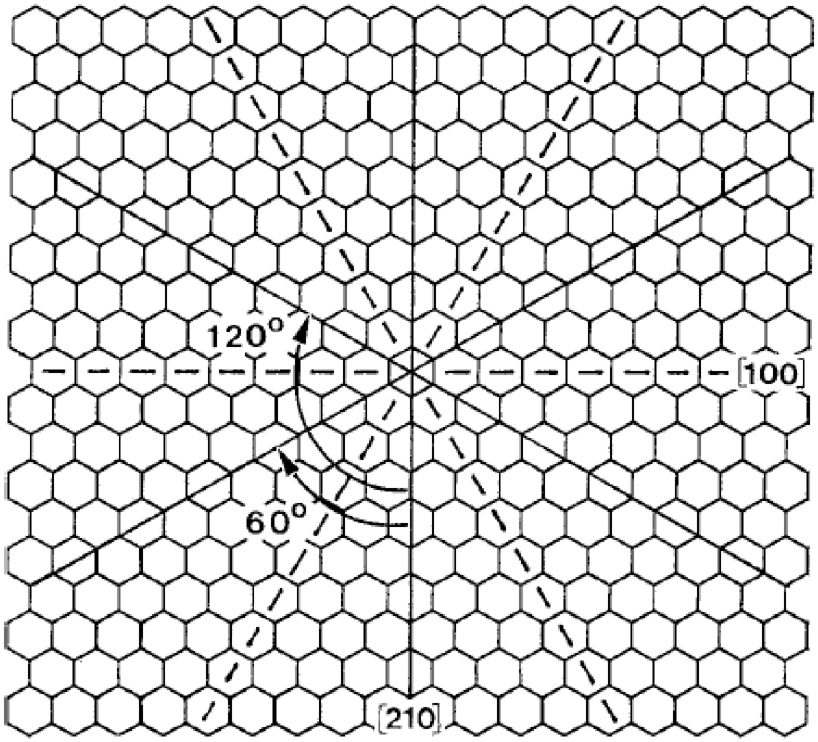

FIGURE 1. Hexagonal network of a single graphite sheet with its symmetry axes.

The rules for closed structures:

$$V - E + F = 2(1 - g)$$

Allows different kinds of closed shell to be built up.

For C_{60}:

$$V = 60$$

$$F = 12 + 20 = 32$$

$$3V = 2E; E = 90$$

Also, for carbon structures containing *x*-sided rings, closed structures must satisfy the condition:

$$\sum (6 - x) n_x = 12(1 - g)$$

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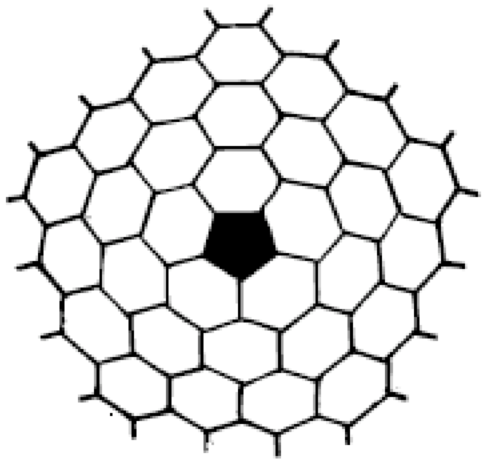

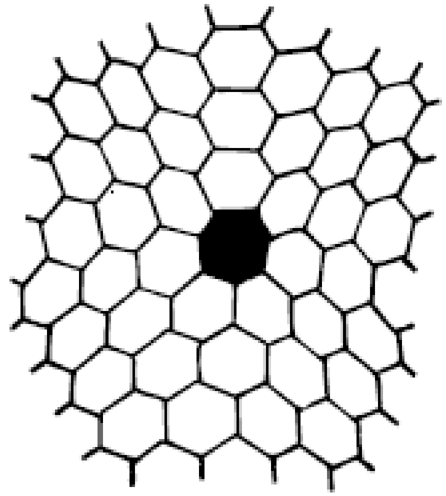

On a flat graphite sheet, the introduction of pentagons or heptagons introduces positive or negative disclinations.

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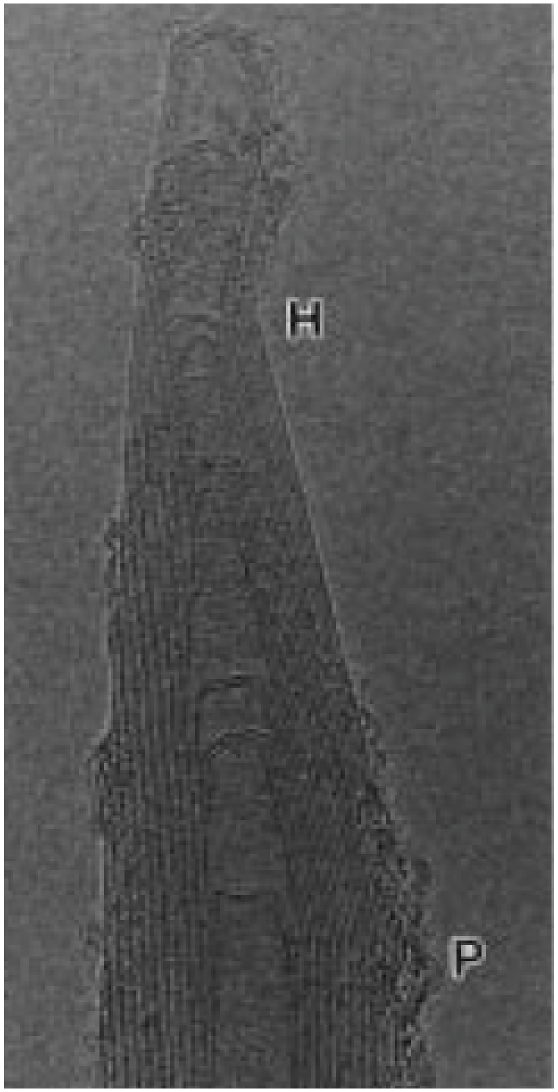

Pentagons and heptagons in a multiwalled carbon nanotube.

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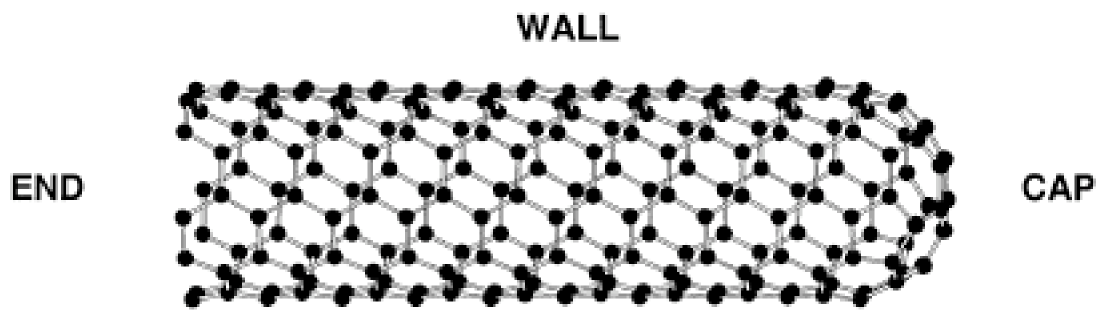
What does a single-walled nanotube look like ?



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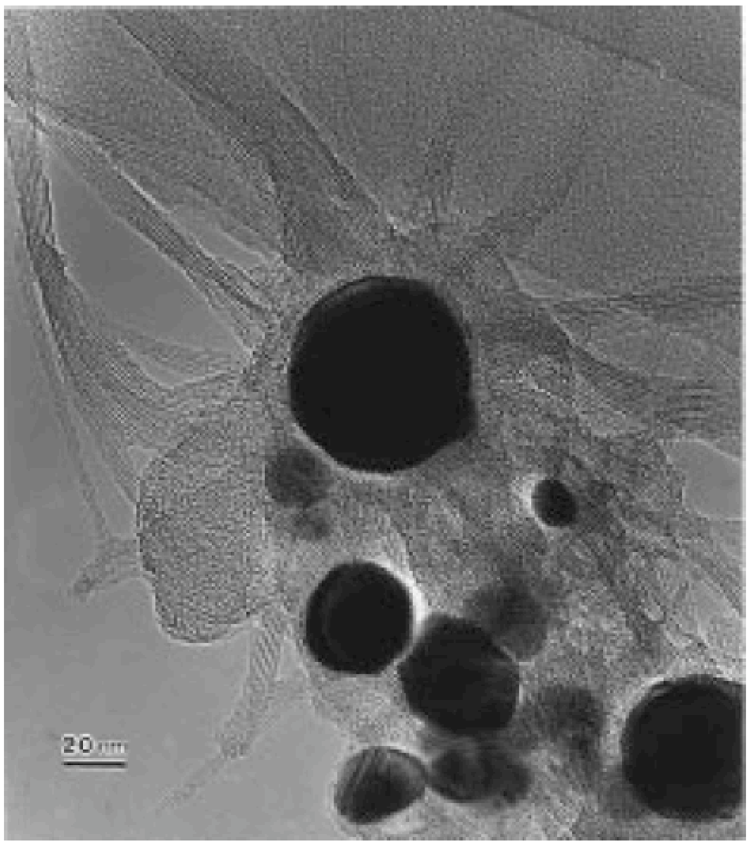
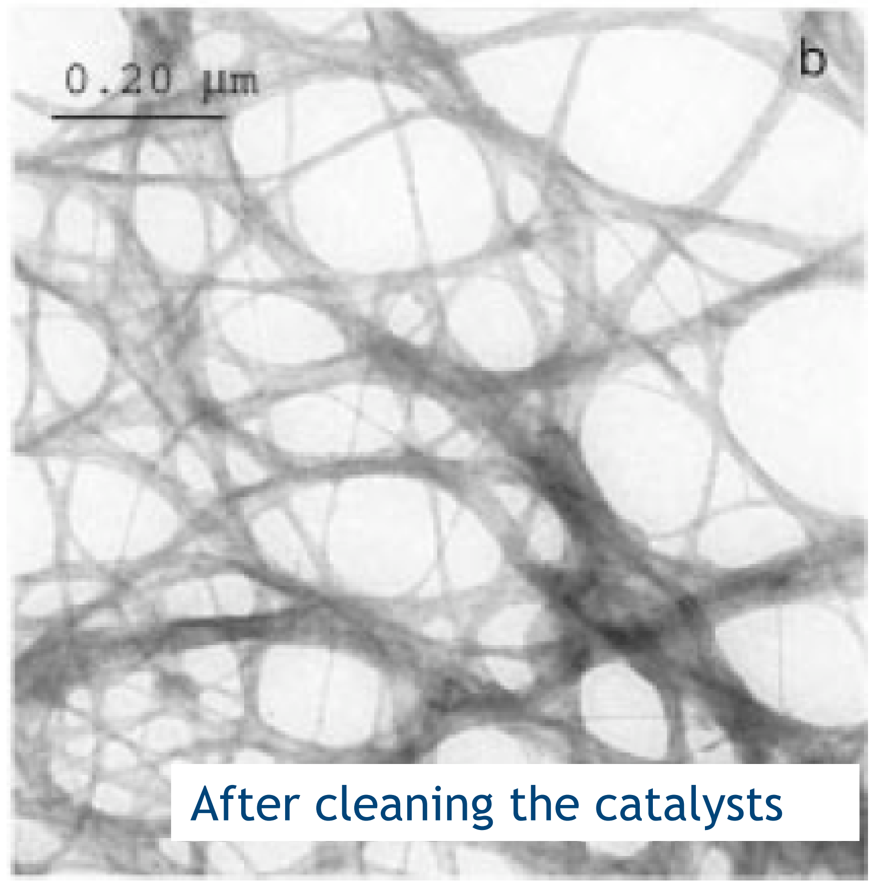


FIGURE 6. Single-shell nanotubes growing radially out from a catalytic particle. Reprinted with permission from ref 38. Copyright 1994 Japanese Journal of Applied Physics.

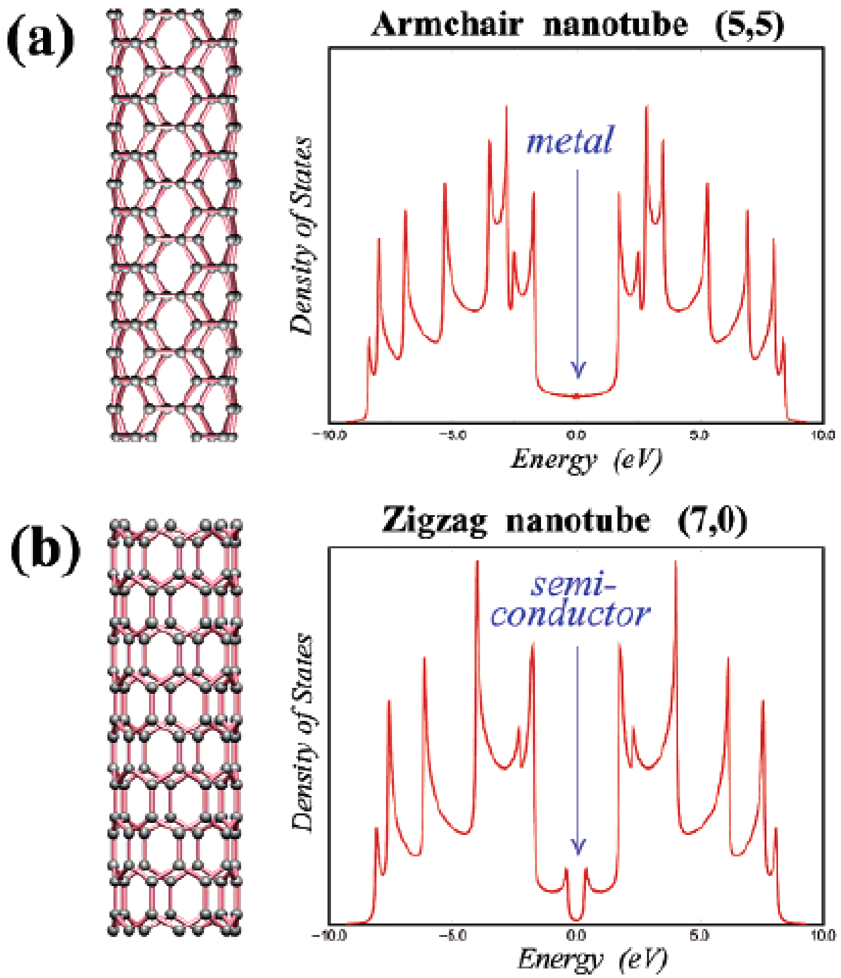
Single-walled nanotubes are made with metal (Co, Ni …) catalysts.



After cleaning the catalysts

Carbon nanotubes

J. C. Charlier, Defects in Carbon Nanotubes, *Acc. Chem. Res.* **35** (2002) 1063.



Depending on how the tubes are curled up, one can obtain metallic or semiconducting tubes.

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J. C. Charlier, Defects in Carbon Nanotubes, *Acc. Chem. Res.* **35** (2002) 1063.

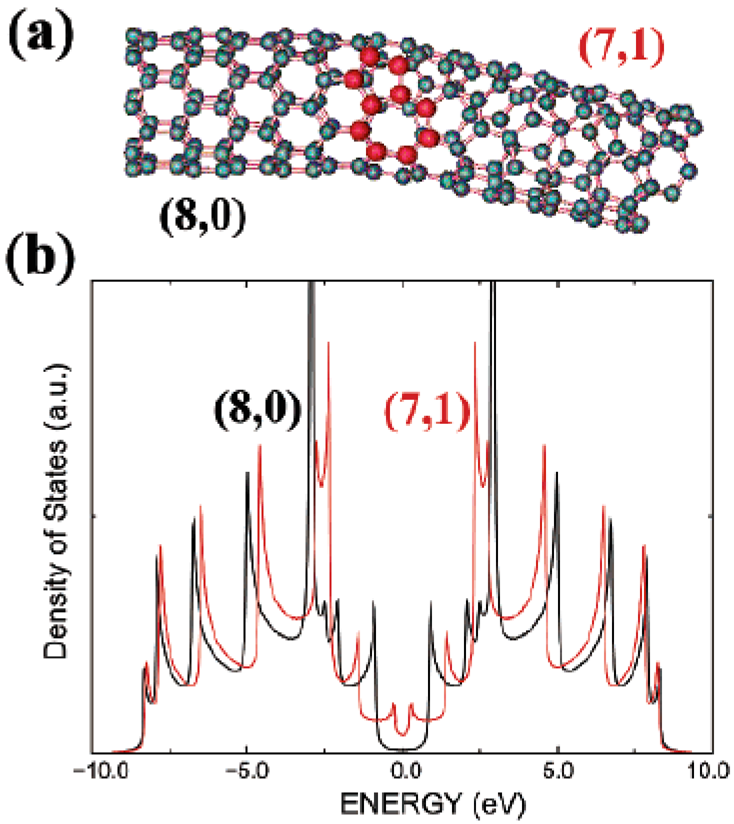


FIGURE 4. (a) Atomic structure of an (8,0)−(7,1) intramolecular carbon junction.[15] The large red balls denote the atoms forming the heptagon−pentagon pair. (b) The electron density of states related to the two perfect (8,0) and (7,1) nanotubes are also illustrated in black and red, respectively.

Defects can be introduced that act as semiconductor-metal junctions.

Carbon nanotubes

J. C. Charlier, Defects in Carbon Nanotubes, *Acc. Chem. Res.* **35** (2002) 1063.

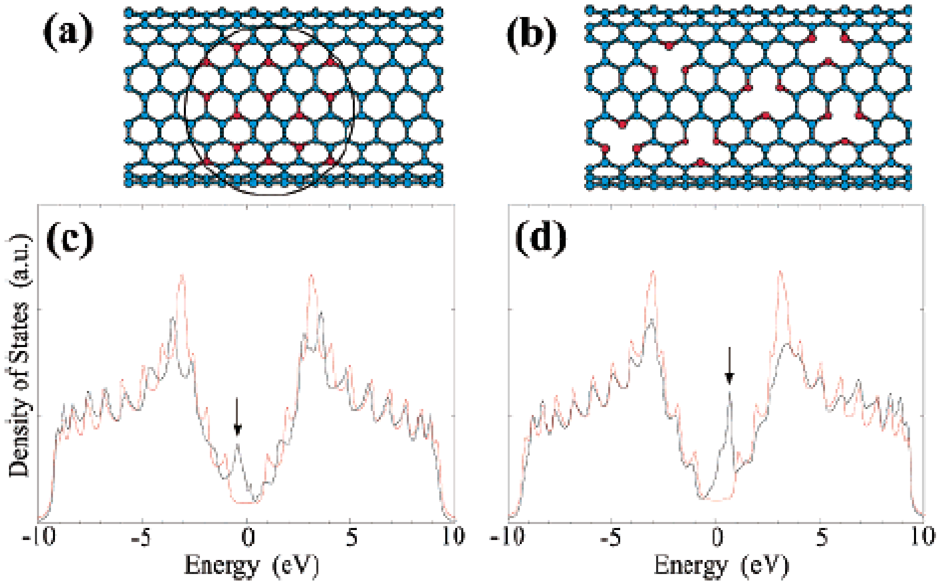
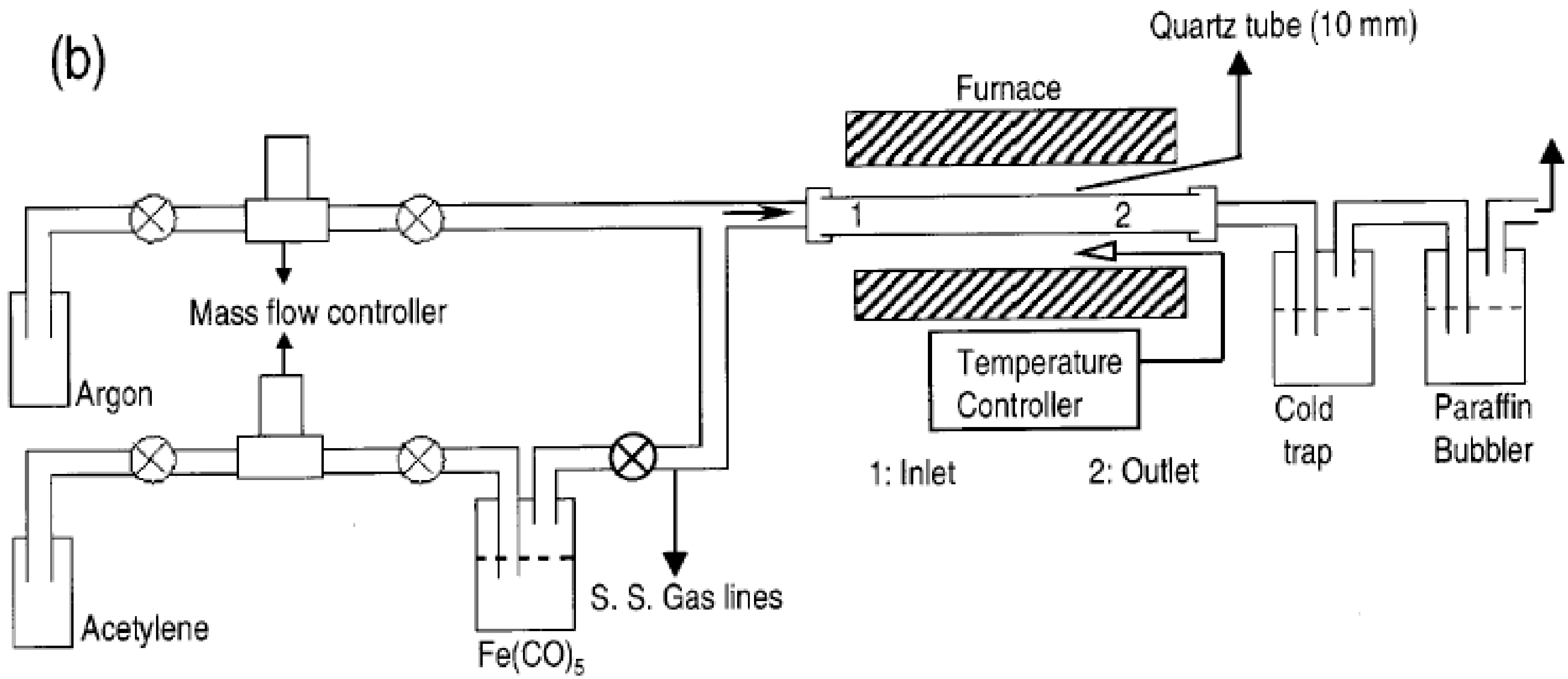


FIGURE 9. Electronic properties of carbon nanotubes doped with (a) boron [B atoms are bonded to three C atoms (B, red spheres; C, blue spheres)] and (b) nitrogen [N atoms are bonded to two C atoms (N, red spheres; C, blue spheres)]. (c) One-dimensional electronic densities of states of a B-doped (10,10) nanotube with a BC_3 island (encircled region) (black curve) compare to an undoped one (red curve). (d) One-dimensional electronic densities of states of a randomly N-doped (10,10) nanotube with pyridine-like defects (black curve) compare to an undoped one (red curve). The Fermi levels are positioned at zero energy. Localized acceptor states (c) and donor states (d) are due to the presence of B and N doping, respectively, and are indicated by arrows.

The electronic sructure of semiconducting carbon nanotubes can be modified by doping the carbon with other atoms.

Carbon nanotubes

C. N. R. Rao and A. Govindaraj, Carbon Nanotubes from Organometallic Precursors, *Acc. Chem. Res.* **35** (2002) 998.

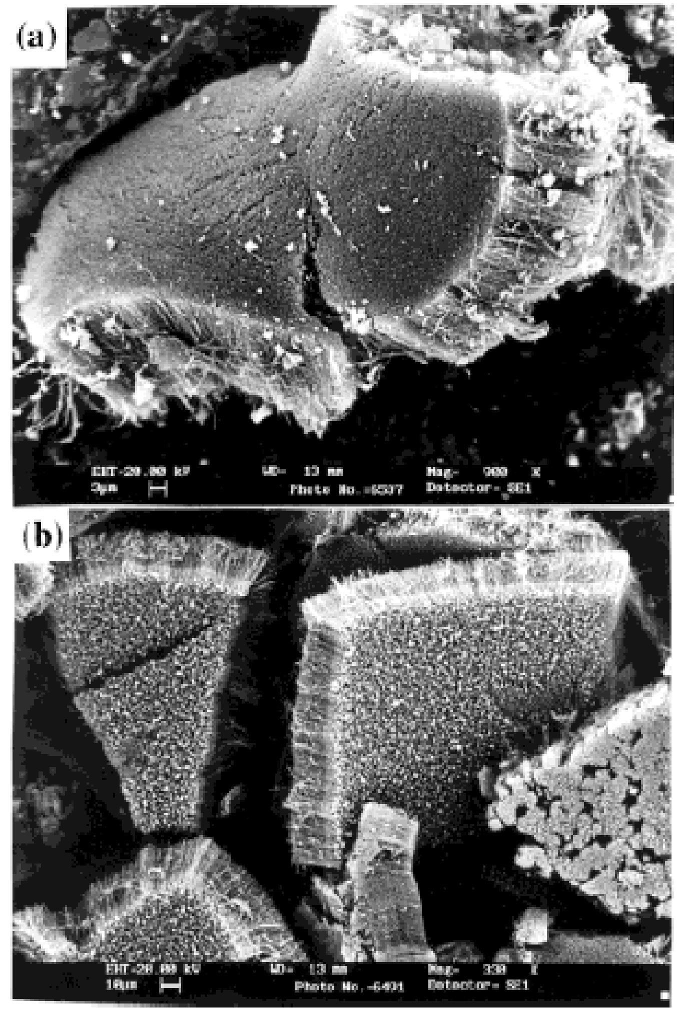


The source of metal is fed in directly with the gas stream.

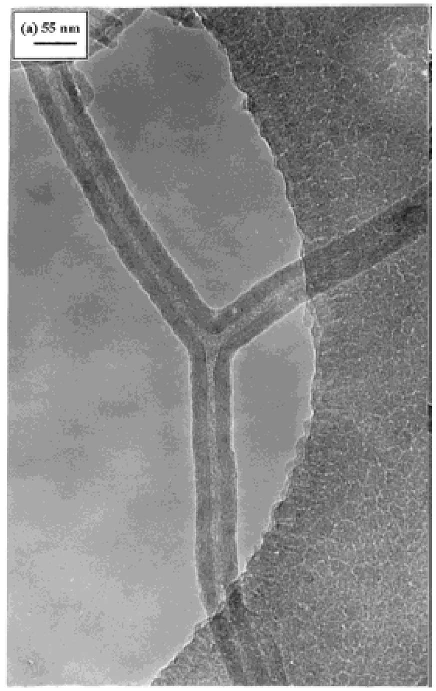
Carbon nanotubes

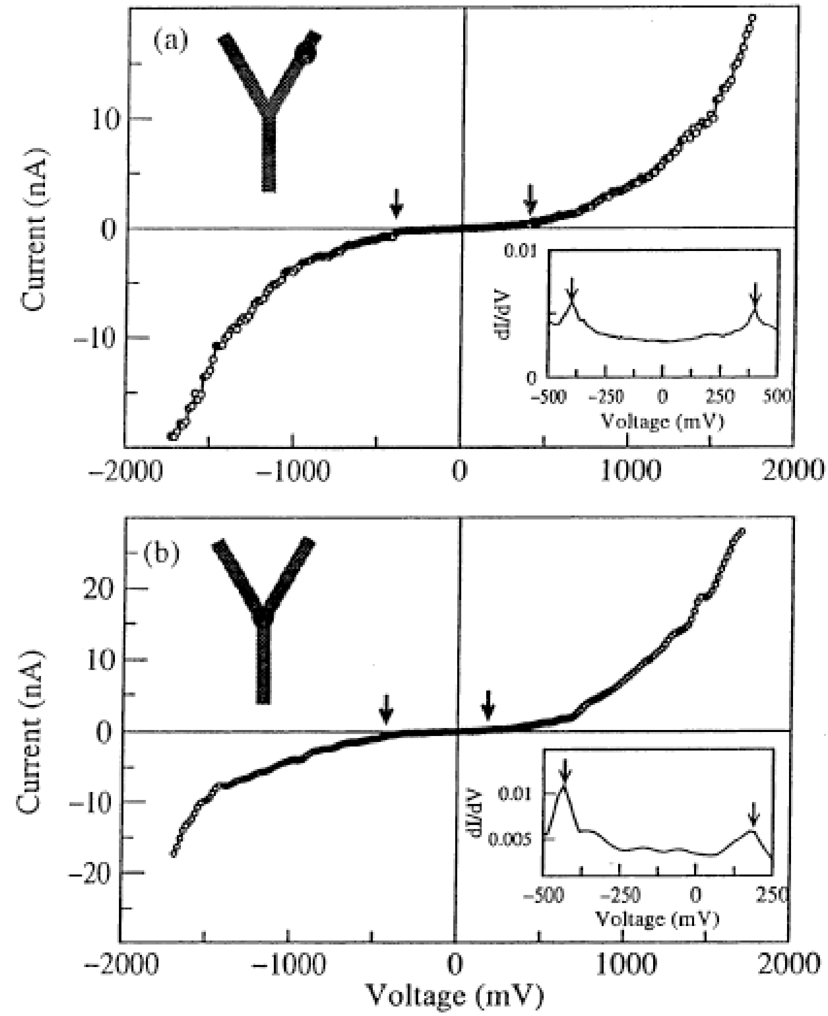
C. N. R. Rao and A. Govindaraj, Carbon Nanotubes from Organometallic Precursors, *Acc. Chem. Res.* **35** (2002) 998.

Dense bundles of nanotubes are obtained in the process of decompositing acetylene and $Fe(CO)_5$



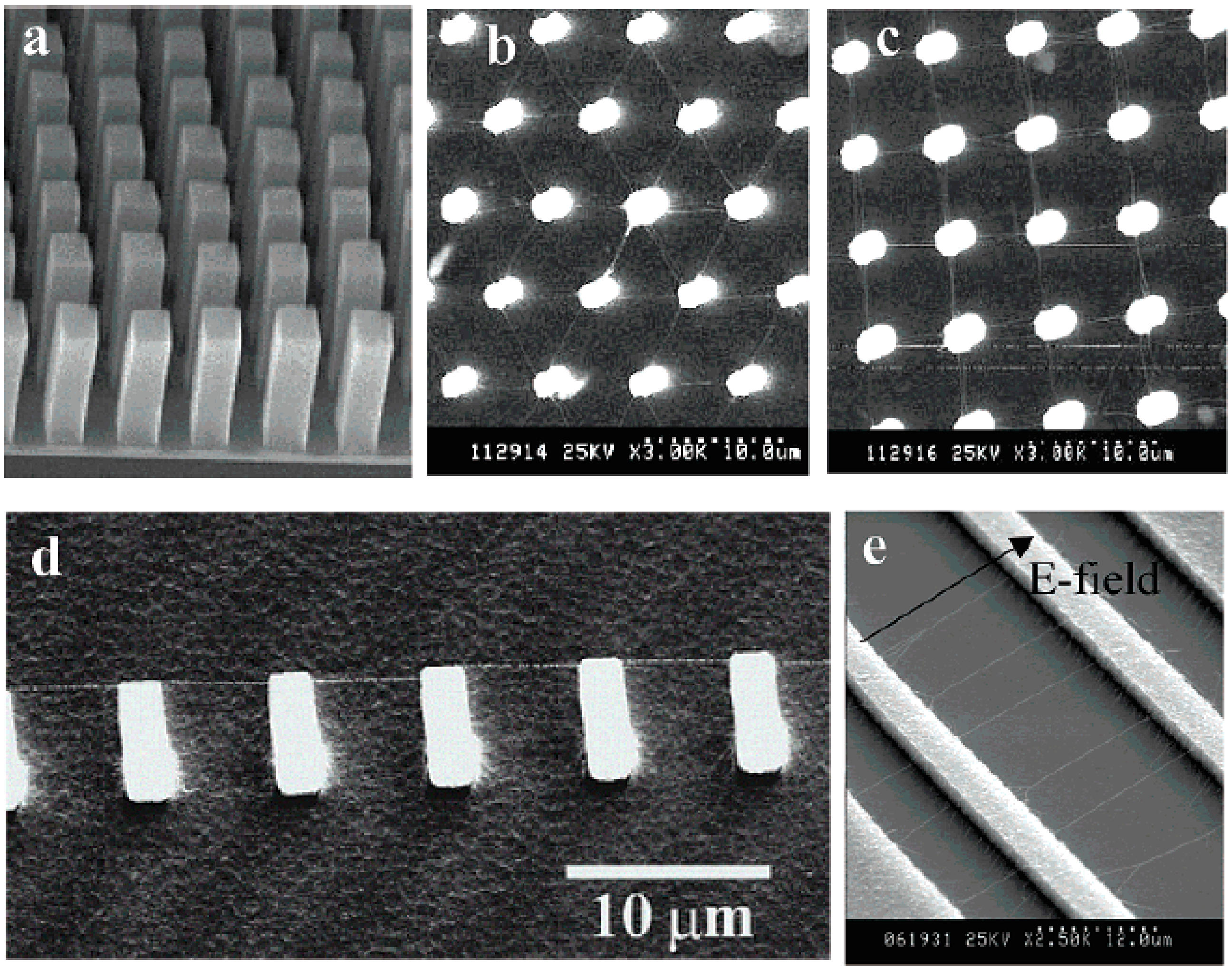
C. N. R. Rao and A. Govindaraj, Carbon Nanotubes from Organometallic Precursors, *Acc. Chem. Res.* **35** (2002) 998.



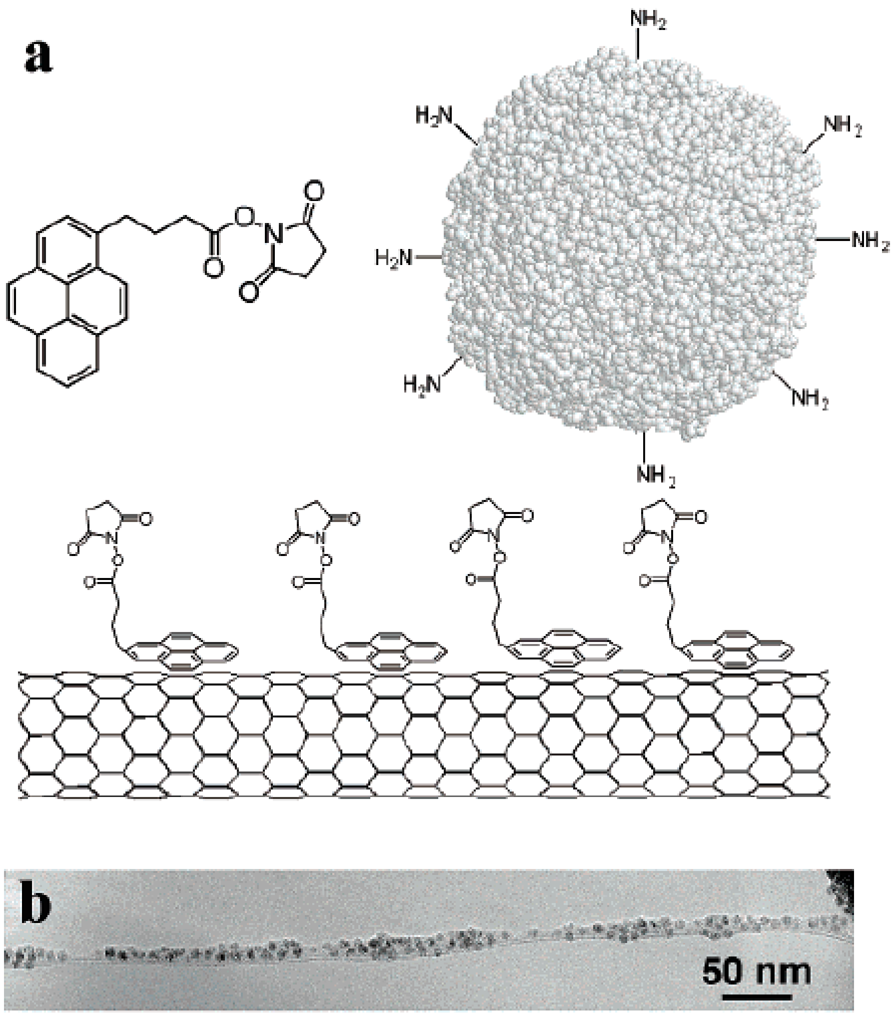


Y-junctions are obtained in the presence of certain precursors. The Y-junctions in STM suggest rectification.

H. Dai, Carbon Nanotubes: Synthesis, Integration and Properties, *Acc. Chem. Res.* **35** (2002) 1035.



H. Dai, Carbon Nanotubes: Synthesis, Integration and Properties, *Acc. Chem. Res.* **35** (2002) 1035.



Ferriting attached covalently to molecules which in turn attach non-covalenty to carbon nanotubes. Such architectures can be employed in sensing devices.