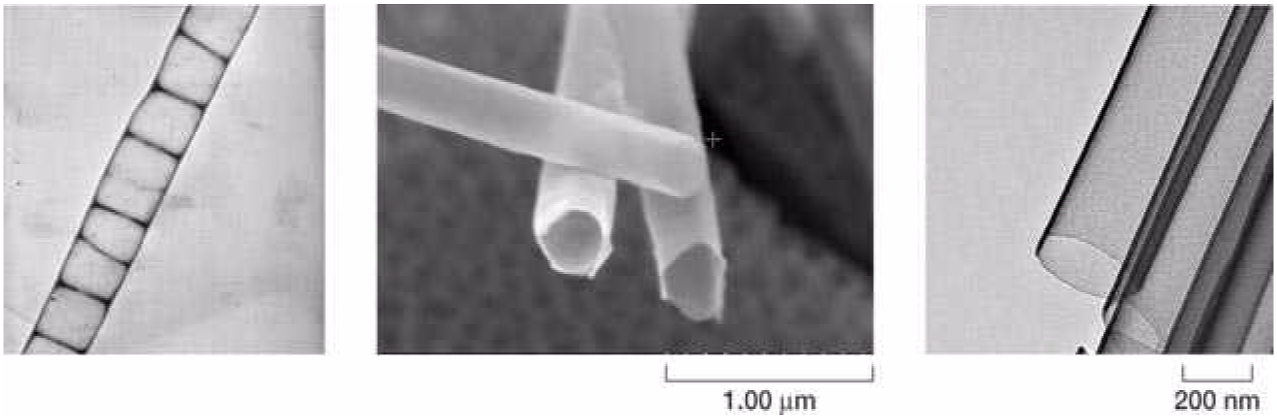
Silicon Carbide Nanotube Synthesized

Carbon nanotubes (CNTs) have generated a great deal of scientific and commercial interest because of the countless envisioned applications that stem from their extraordinary materials properties. Included among these properties are high mechanical strength (tensile and modulus), high thermal conductivity, and electrical properties that make different forms of single-walled CNTs either conducting or semiconducting, and therefore, suitable for making ultraminiature, high-performance CNT-based electronics, sensors, and actuators. Among the limitations for CNTs is their inability to survive in high-temperature, harsh-environment applications. Silicon carbon nanotubes (SiCNTs) are being developed for their superior material properties under such conditions. For example, SiC is stable in regards to oxidation in air to temperatures exceeding 1000 °C, whereas carbon-based materials are limited to 600 °C. The high-temperature stability of SiCNTs is envisioned to enable high-temperature, harsh-environment nanofiber- and nanotube-reinforced ceramics. In addition, single-crystal SiC-based semiconductors are being developed for high-temperature, high-power electronics, and by analogy to CNTs with silicon semiconductors, SiCNTs with single-crystal SiC-based semiconductors may allow high-temperature harsh-environment nanoelectronics, nanosensors, and nanoactuators to be realized.

Another challenge in CNT development is the difficulty of chemically modifying the tube walls, which are composed of chemically stable graphene sheets. The chemical substitution of the CNTs’ walls will be necessary for nanotube self-assembly and biological- and chemical-sensing applications. SiCNTs are expected to have a different multiple-bilayer wall structure, allowing the surface Si atoms to be functionalized readily with molecules that will allow SiCNTs to undergo self-assembly and be compatible with a variety of materials (for biotechnology applications and high-performance fiber-reinforced ceramics).

The NASA Glenn Research Center has been collaborating with Rensselaer Polytechnic Institute to realize the synthesis of SiC nanotubes. Several methodologies, including chemical conversion of CNTs to SiCNTs, direct SiCNT growth on catalyst, and template-derived SiCNTs (where the template acts as a nanomold) are being explored. In the template synthesis, polymer infiltration has resulted in polycrystalline/amorphous nanofibrils and nanobamboo, whereas chemical vapor deposition into these nanomolds has resulted in polycrystalline/amorphous hollow, uniform tubes.



Left: Transmission electron microscope image of SiC nanobamboo, 200 nm in diameter. Center: Scanning electron microscope image of chemical-vapor-deposition-template SiCNTs, 200 nm in diameter. Right: Transmission electron microscope image of chemical-vapor-deposition-template SiCNTs, demonstrating thin, uniform walls.

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