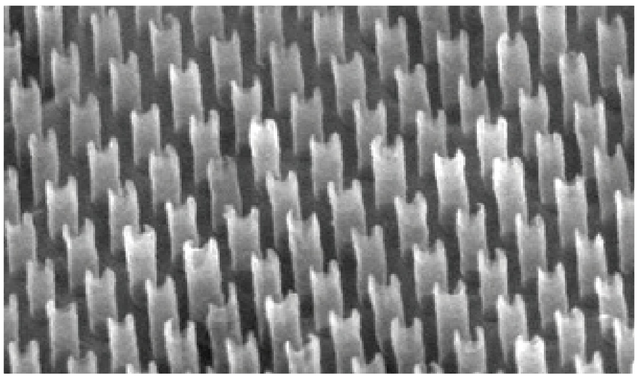
Uncooled Infrared Detector Made Possible with Controlled Carbon Nano-Tube Array

Accomplishment: The processing of a highly ordered array of highly uniform carbon nanotubes with an electronic-grade junction to a silicon semiconductor substrate was developed. Dual band infrared detection was demonstrated in uncooled operation for the first time in these devices.



Impact: This new material system gives a broadly enabling platform for future multi-spectral infrared and biochemical sensing applications. Multi-band detection can be achieved over a broad spectral range from near infrared to far infrared by building arrays with several distinct nanotube diameters, replacing several conventional detectors with a single detector array. This capability is important for miniaturization and for providing new sensing capabilities in platforms with limited payload such as satellites and unmanned air vehicles (UAVs).

Motivation and Approach: Carbon nanotubes are a molecular form of carbon that can be visualized as a planar hexagonal net of carbon atoms (a graphene sheet) that has been rolled and joined at the edges to form a tube. Carbon nanotubes are typically less than a few tens of nanometers in diameter and up to several millimeters in length, and can have a hemispherical cap on one or both ends. Carbon nanotubes have exceptional electrical, thermal, chemical and mechanical properties that motivate and enable completely new functions and capabilities, including structural components with superlative strength-to-weight; microscopic electronic circuits; sensors and transmitters with unique characteristics; and controlled drug delivery. A major obstacle to the realization of nanotube capabilities has been the lack of approaches for the mass production of high quality and high uniformity carbon nanotubes, and for organizing them into useful architectures.

The present work develops the template-assisted chemical vapor deposition method to produce a highly ordered array of high quality carbon nanotubes of controlled diameter, length and spacing. This process deposits a uniform, high purity aluminum film on a silicon semiconductor substrate. Precision anodization transforms the aluminum to aluminum oxide and forms a uniform nano-pore array in the aluminum oxide that stops precisely at the silicon interface. A nanoparticle of iron is deposited at the bottom of each nano-pore and a carbon nanotube is subsequently grown at high temperature on each iron nanoparticle. An electronic-grade heterojunction contact is formed between the carbon nanotubes and the silicon semiconductor substrate. This unique architecture gives a broadly enabling base technology for a range of applications. The first uncooled dual-band infrared heterojunction detector was demonstrated in this on-going effort. Conversion of electromagnetic radiation to heat by the carbon nanotube array has been conceived and is being explored as a possible approach for protection from electromagnetic pulses.

Team: This research was conducted by Prof. Jimmy Xu and his research team at Brown University. Collaborators include Dr. Gail Brown (Materials and Manufacturing Directorate), Dr. Dave Cardimona and Dr. Dan Huang (Space Vehicles Directorate) and Dr. Richard Osgood (Army Natick Center). Funding was provided by the Air Force Office of Scientific Research (Dr. Hugh DeLong and Dr. Gernot Pomrenke, Program Managers) and by the Army Research Office (Bill Clark, Program Manager).