AIRCUITY®

OptiNet® Structured Cable

High Performance Air and Data Communications Cable Enabled with Nanotechnology

White Paper Series

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High Performance Air and Data Communications Cable Enabled with Nanotechnology

Aircuity, Inc. (Newton, MA) has created a new type of structured cable as an integral component of their OptiNet® Facility Monitoring System. The cable combines digital data communications, low voltage power, analog signals and a hollow inner conduit, known as MicroDuct™, to enable the transport of air samples within the patent pending cable. The MicroDuct is able to transport air samples for sensing a wide variety of gases, vapors, volatile organic compounds (VOCs) and particles over long distances with very low loss or contamination. Installation costs have also been significantly reduced by combining the integral data, power, and signal wires, along with the MicroDuct, into one all inclusive, plenum rated, structured cable.

The key to achieving this breakthrough performance is to have a flexible inner lining within the MicroDuct that is both highly inert and also very conductive electrically. This is made possible in part to an inner lining constructed of a fluoropolymer resin (FEP) similar to Teflon®, compounded with a small amount of a remarkable new material known as *carbon nanotubes*.

Carbon Nanotubes

Carbon nanotubes are a result of the recent explosion in the science of *nanotechnolog*y - the study of materials at the atomic level. Nanotechnology is at the forefront of today's scientific communities as it leads to the promise of lighter, stronger, and more energy efficient products. Carbon nanotubes are an unusual form of a very small scale carbon structure in the same category as *buckyballs* or *Buckminsterfullerenes*, and are sometimes referred to as *buckytubes* or *tubular fullerenes*. Nanotubes are made from single or multiple layers of carbon atoms that when flat, would be similar to graphite as shown in Figure 1. However, when these layers are rolled up into a seamless cylinder, the properties of this carbon material change dramatically. What results is an extremely thin, long and very strong structure. Single-wall (one layer of atoms thick) carbon nanotubes are about 1 nanometer in diameter, with lengths in the micron range making them thousands of diameters long.

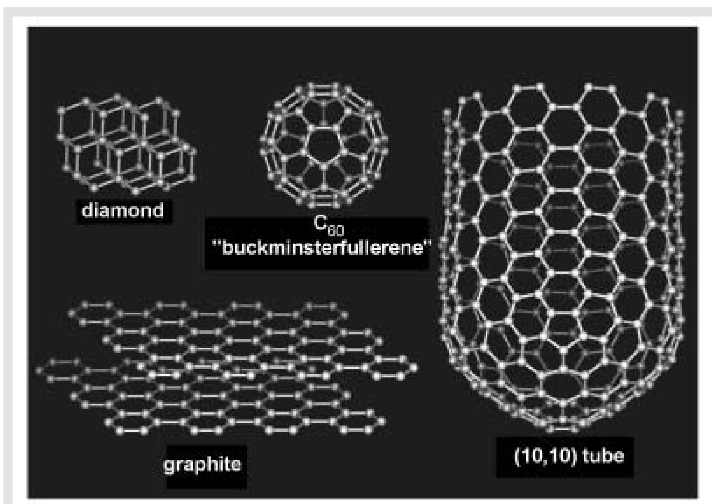


Figure 1: Carbon structures.

Carbon nanotubes have very unusual properties. They are the strongest substance known to exist, up to 100 times stronger than steel at one-sixth the weight, yet the substance is still quite flexible. It can stretch beyond 20 percent of its resting length, be bent over double, and even tied into a knot and released with no resulting defect. Carbon nanotubes are also the best known conductors of heat, better than even diamonds.

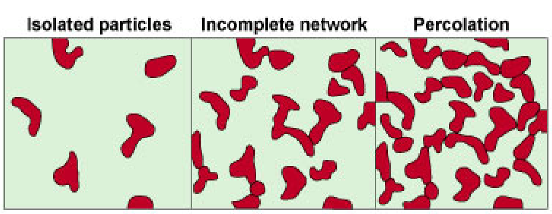
The type of carbon nanotubes that are used in OptiNet cable have a molecular structure that makes them into true metals just like gold or copper. As such, they are excellent conductors of electricity, in some cases equal to or better than copper or gold. They are also relatively inert and non-reactive chemically.

Suitability for Transporting Air and Data Communications

Due to their long, thin structure, carbon nanotubes tightly bond and intertwine with the long polymer molecules of plastics to form a tightly wedded mixture that is electrically conductive. Although other materials such as carbon black can be used to make plastic that is electrically conductive, it requires large amounts of the carbon black, which in turn changes the physical and chemical properties of the resulting plastic composite. In particular, it affects the inert properties of the plastic such that VOCs and some gases and vapors may be adsorbed or desorbed from the conduit walls. This makes the use of carbon black in the conduit unsuitable for most air sampling applications.

Nanotubes however are well suited for use with air sampling applications for several reasons. First of all, only very small amounts of carbon nanotubes are required to achieve high electrical conductivity due to their very high length to width ratio (over a thousand to one), coupled with their own high electrical conductivity properties. High conductivity in plastics is achieved by forming long chains of conducting pathways throughout the plastic material, a condition known as percolation.

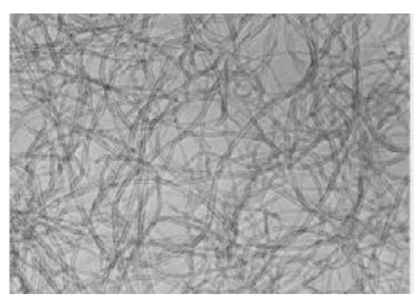
Figure 3: Networking of conductive elements or percolation.



As seen in Figure 3, a material like carbon black with a low length to width ratio requires a significant amount of material to form interconnecting matrixes of conductive material to achieve percolation.

In comparison, as seen in Figure 4 (a picture of dispersed nanotubes in plastic), the nanotube's long structure creates long conductive elements, effectively like very thin wires, to achieve percolation with very small amounts of nanotube material.

Figure 4: Photomicrograph of carbon nanotubes in plastic to achieve percolation.



Lastly, the carbon nanotube's metallic, inert properties, combined with their very small size, and tight bonding to FEP plastics, makes the resultant mixture able to transport VOCs and other gases with extremely low absorption, adsorption, desorption or off-gassing so as not to change the air sample's properties.

Aircuity's Application for Carbon Nanotubes

Despite the relatively high cost of carbon nanotubes, Aircuity is able to produce the MicroDuct conduit economically by blending the carbon nanotubes with the FEP fluoropolymer resin. As a result of the innovative use of nanotechnology, there now exists an economical, high performance cable choice for collocating data communications and air sample transport from locations throughout a facility.

As a key element of Aircuity's OptiNet Facility Monitoring System, the carbon nanotube based structured cable can enable cost effective, high accuracy sensing and control of a facility's indoor environment. As a networked air sampling and data infrastructure, OptiNet enables dozens of room, air handler, or duct locations to be sensed for many different environmental parameters such as humidity, carbon dioxide (CO_2), carbon monoxide (CO), fine particles, TVOCs and more, using only a single set of high quality sensors. OptiNet can also be integrated with any building control system for improved building control. Continuous commissioning via web based reporting is also provided using the industry's first artificial intelligence based expert system to analyze a building's delivered energy and environmental performance. OptiNet is particularly applicable for Green Building facilities due to the large number of cost effective LEED points it can secure by reducing building energy costs and monitoring a facilities' indoor environmental quality. Other applications include use in the education, healthcare, laboratory and office building markets.

About Aircuity

Aircuity, Inc. is the leading manufacturer of integrated sensing and control solutions that cost-effectively reduce building energy and operating expenses while simultaneously improving indoor environmental quality. Aircuity's goal is to optimize building ventilation for energy efficient performance without sacrificing occupant comfort, health or productivity.

The company's systems are suitable for a broad range of commercial building applications where energy efficiency and enhanced indoor environmental quality are important, including offices, laboratories, hospitals, educational institutions, museums, convention centers and sports arenas.

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OSCWP F101606