Nano Science, Technology and Industry Scoreboard

Carbon Nanotube Air Filter Neutralizes Betacoronavirus

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In collaboration with Tortech Nano Fibers Ltd. and Q-Flo Limited, a team of researchers at the University of Cambridge has developed a self-sanitized carbon nanotube (CNT) air filter proven to achieve full deactivation of a betacoronavirus and adeno-associated virus retained on filter surfaces.

Virus-carrying particles and droplets are a primary means of transmission for respiratory diseases. The removal of these particles and droplets from the environment through filtration significantly reduces the risks of viral infection. But viruses may remain active on filtration surfaces. Cambridge University's CNT filter prototype achieved 99% air purification of a room within 10 minutes.

Coronavirus: A Global Challenge

Coronavirus disease 2019 (COVID-19) had a devastating impact on human health and the global economy. It is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was first identified in China in December 2019.

Respiratory particles that can enter the lung may also remain suspended in the air for hours, traveling over distances of tens of meters. These particles can contain active SARS-CoV-2 virions for 3 hours or more, increasing infection rates in enclosed environments.

Respiratory liquid aerosols (5 mm droplet sizes approximately) are produced through coughing, sneezing, speaking and breathing. They are thought to be an important vector for viral transmission. Therefore, disrupting these vectors is an important step in the prevention of viral transmission.

Air filtration and recycling have been proposed as a solution to this problem. Filtration media must allow for high air flow and low-pressure loss while allowing for high rate of viral removal, trapping and deactivation.

Although there has been significant progress in filtration materials, the Cambridge University team reports that much of the effort has focused on functionalizing face coverings with nanomaterials. These methods cannot be implemented in HVAC systems because they are not easily scalable over larger areas and have not been proven to possess disinfection capabilities in closed filtration systems.

Nanofibers display high aerosol filtration efficiency and low pressure drops. Carbon nanotubes (CNTs), with diameters in the order of tens of nanometers are effective nanofiber filters. Some techniques involve coating existing filters with nanotubes using dispersion coating or chemical vapor deposition (CVD). Alternatively, free-standing CNT membranes are attached to conventional microfiber backings. However, these techniques require costly synthesis.

In this context, the Cambridge University team was the first to develop a mass-producible air filter. It displays commercial HEPA (high-efficiency particulate air) pressure drop and efficiency, while being simultaneously self-sanitizing.

A Brief Introduction to Carbon Nanotubes

Carbon is the fourth most abundant element in the universe. Various arrangements of carbon atoms take on a variety of forms known as allotropes. These allotropes have unique properties of strength and electrical conductivity.

At room temperature, carbon forms two classical allotropes: diamond and graphite. In 1985, a third allotrope was discovered: fullerene. It contains sixty symmetrically arranged carbon atoms. In 1991, carbon nanotubes came into public awareness when Sumio Iijima reported his findings about needle-like carbon tubes in the journal Nature. Carbon nanotubes are members of the fullerene family. In 2004 came the discovery of graphene.

Carbon nanotubes (CNTs), as the name implies, are rolled up “sheets” (“tubes”) of graphene. They are single-walled (SWCNTs), less than 1 nanometer (nm) in diameter, or multi-walled (MWCNTs), consisting of nested single-wall carbon nanotubes bound by van der Waals interactions, with diameters reaching more than 100 nm.

Techniques to produce CNTs include arc discharge, laser ablation and chemical vapor deposition (CVD). Most of these processes are carried out in vacuum conditions. In the CVD process, a metal catalyst combines with carbon-containing reaction gases to form carbon nanotubes. The Cambridge University team used a floating catalyst CVD (FCCVD) process to form a CNT mat.

Carbon nanotubes outperform diamond as thermal conductors. Their high surface area combines with their unique ability to carry chemical compounds after surface modification to make them an ideal high-reactivity nanoscale catalyst and conductor.

A Novel Carbon Nanotube Filtration System

The Cambridge University team developed an active filtration system based on an electrically conductive CNT mat that thermal flashes can rapidly sanitize via resistive heating to temperatures above 800C within seconds or less.

The free-standing CNT material has 10 to 100 nm pores serving as the filtration media and electrically conductive network. The CNT mats were stabilized with perforated polyester with approximately 100 mm sized hole. These hybrid CNT-polyester filters meet commercial HEPA standards for HVAC filtration. This includes filtration efficiency, pressure drop, heating rate and disinfection capabilities.

This is an active filter because it neutralizes viral and other pathogenic threats, in addition to capturing them. The active filter can be flash heated to 1300C within seconds, leading to full viral inactivation. This was shown on adeno-associated virus 9 (AAV9), and betacoronavirus heated to 800C on a CNT substrate.

This heralds a major breakthrough in the fight against respiratory diseases of the kind seen during the COVID-19 pandemic.

Read the original article on AZoNano.