CAN WE INCREASE THE SAFETY OF CARBON NANOTUBES?

FOR CARBON NANOTUBES TO TAKE ADVANTAGE OF THE LITHIUM BATTERY MARKET, more emphasis must be placed on innovations around safety.

Carbon nanotubes, nano-size cylinders made of carbon atoms, are attracting renewed interest for their role in the future of cars.

Industry reports project that the global market for these nanomaterials will reach US$28.74 billion by 2030 after health concerns thwarted their early growth trajectory, says Hideyuki Hisashi, a materials scientist and president of nanotech consultancy, Dr. GOO Ltd., based in Oita, Japan.

"Carbon nanotubes, discovered by Japanese researchers in 1991, initially garnered attention for their extraordinary strength, conductivity, and adaptability for use in semiconductors, batteries and medicine. However, findings about the potential for negative health effects have led to dwindling enthusiasm," explains Hisashi. "Greater efforts to ensure the safety of carbon nanotubes are crucial for the market to expand."

THE PROMISE IN NANOTUBES

A major factor for nanotubes' potential is their use in lithium-ion batteries, expected to experience a seven-fold increase in demand between 2022 and 2030. Lithium-ion batteries are an integral component of electric vehicles that determine their cost and performance. As carbon nanotubes enhance electrical conductivity, using these nanomaterials along with carbon powders as additives in the batteries promise to improve energy efficiency.

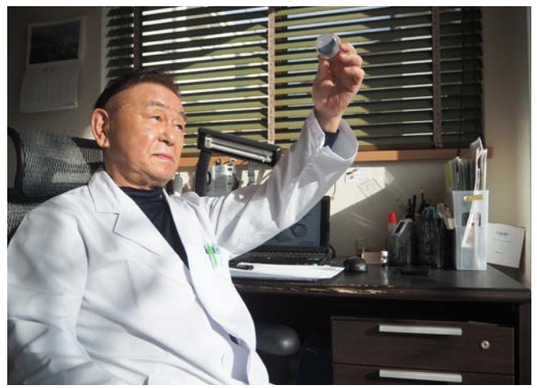
However, organizations in the European Union have proposed bans on carbon nanotubes. For example, since 2019, the Swedish government-funded organization, ChemSec, has included carbon nanotubes in its 'Substitute It Now' list, which identifies chemicals with potential threats to health and the environment. The nanotubes inclusion was based on the result of laboratory studies in cells and mice which showed DNA damage and inflammation, both key triggers for cancer, in certain types of carbon nanotubes[1].

Europe isn't the only centre of concerns. "In Japan, research interest waned after media reports spurred fears of carcinogenicity in all types of carbon nanotubes in 2015. This was despite the coverage highlighting concerns with one specific type of carbon nanotube with a long, rigid structure resembling that of asbestos. This type of nanotube, which is no longer being produced, showed carcinogenic properties in mice when inhaled," says Hisashi.

ADDRESSING COMPLEXITY

Materials scientists say that in risk assessments, carbon nanotubes are grouped into a single substance category despite their differences[2]. Carbon nanotubes can be broadly categorized into single-wall and multi-wall carbon nanotubes, with the former comprised of a single layer of hexagonally arranged carbon atoms, and the other of multiple layers. The nanotubes exhibit distinct and unique characteristics that are dependent on various factors including diameter, length, arrangement of carbon atoms within the nanotube, and structural irregularities.

Studies in mice have found that specific kinds of multi-wall carbon nanotubes induce a type of cancer associated with asbestos, but no similar evidence has been found for single-wall carbon nanotubes[3]. Furthermore, studies do not often account for the diverse forms and functionalities that result from the way they were synthesized. As a result, Hisashi emphasizes the importance of accounting for these factors, synthesis in particular, when assessing risk.



▲ **(top) Hideyuki Hisashi, president of Dr GOO Ltd., in Oita, Japan. (bottom) Carbon nanotube powder is formed by aggregates of 40 to 50 microns (left), dozens of these aggregates combine to form a granule (right).**

SAFETY INNOVATIONS

While assessments of each carbon nanotube type are imperative, Hisashi says that accelerating innovation to enhance their safety is essential in order for carbon nanotubes to contribute to the next generation of technology.

A major health concern is the inhalation of carbon nanotubes during the manufacturing process of resins. Workers are exposed to carbon nanotube dust in situations such as when kneading carbon nanotubes into resins, to reinforce the material's strength, or for adding electrical conductivity.

"SAFER CARBON NANOTUBES WILL ENABLE MANUFACTURING IN A WIDER RANGE OF FACILITIES AT LOWER COST."

When carbon nanotubes in a powdered form are poured into hoppers that dispense fine particulates, the nanotubes disperse into the air due to their small bulk density. To address this, researchers have explored granulation techniques commonly used in drugs to form the fine powder into larger granules and tablets. Hisashi explains that while this helps prevent particles from dispersing in the air, transportation can cause granulated nanotubes to crumble back into fine powder due to the binding methods typically used for carbon nanotubes, making them hazardous again.

He believes that the coating technique, in which micron-sized clusters of nanotubes are covered with a polymer layer and then granulated and solidified into 1- to 2-mm spheres, can further reduce cellular uptake and inflammation when inhaled as well as airborne diffusion. Originally developed to facilitate particle flow of pure carbon powder, Hisashi says the method is applicable to all types of carbon nanotubes. "Carbon nanotubes with a powder particle size of less than 10μm have a high risk of being inhaled and ingested when handled, so it is important to coat them to reduce scatter," he says.

GLOBAL RELEVANCE

In addition to preventing dispersal, other research groups have explored methods to enhance safety through different strategies. One method involves modifying the nanotube surface with functional groups that mitigate adverse biological responses. Additionally, ensuring the purity and consistency of the raw materials used in nanotube synthesis is crucial, as contaminants and surface defects can be toxic. Safety measures must address the entire lifecycle of carbon nanotubes, including methods for disposal, such as through enzymes.

"Given the extra precautions currently required for handling carbon nanotubes, the facility costs for lithium-ion batteries using carbon nanotubes remain high. Nevertheless, numerous companies invest in expensive equipment with exceptional safety standards because they recognize the market potential," says Hisashi. "As the demand for lithium-ion batteries increases, safer carbon nanotubes will enable manufacturing in a wider range of facilities at lower cost."

He adds that safer handling has strong implications for manufacturers in East Asia which currently lead global production.

"In Japan, regulatory requirements and societal sentiment have pushed companies to make substantial investments in safe facilities for carbon nanotube-related initiatives. As a result, many companies have stopped working with carbon nanotubes," he says.

Ensuring safety remains a vital step needed for the carbon nanotube market to truly flourish and experience significant growth, he adds. ■

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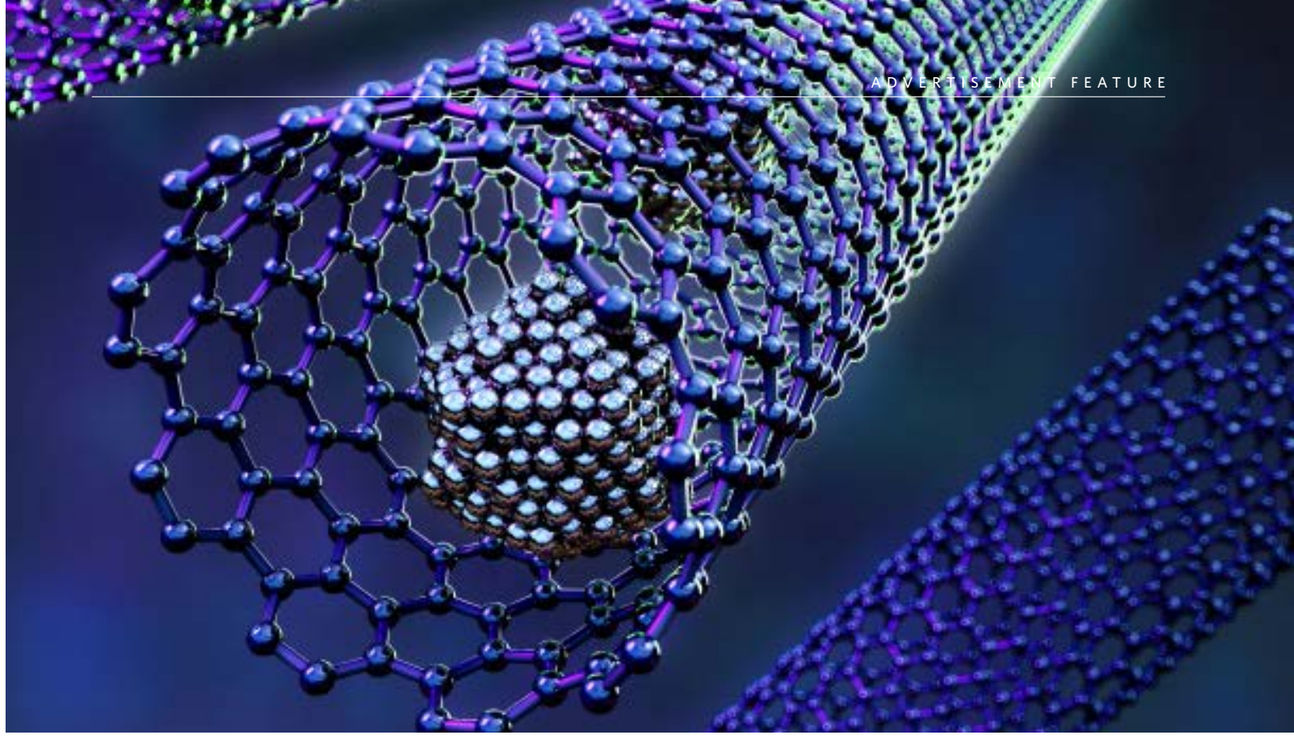

▲ **Ensuring the safe manufacturing and handling of carbon nanotubes is essential if they are to be employed in advanced technologies.**

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