Researchers turn plastic bottle waste into ultralight supermaterial with wide-ranging applications

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Researchers from the National University of Singapore have found a way to turn plastic bottle waste into ultralight polyethylene terephthalate (PET) aerogels that are suitable for various applications, including heat insulation and carbon dioxide absorption. From left: Mr Khac Duyen Le, Research Engineer, Department of Mechanical Engineering, NUS Faculty of Engineering; Mr Leung Hoe Inn, Ryan, final-year undergraduate student, Department of Mechanical Engineering, NUS Faculty of Engineering; Professor Nhan Phan-Thien, Department of Mechanical Engineering, NUS Faculty of Engineering; Associate Professor Hai Minh Duong, Department of Mechanical Engineering, NUS Faculty of Engineering; Dr. Xiwen Zhang, Singapore Institute of Manufacturing Technology, Agency for Science, Technology and Research. Credit: National University of Singapore

A team led by researchers from the National University of Singapore has made a significant contribution towards resolving the global issue of plastic waste, by creating a way to convert plastic bottle waste into PET aerogels for many useful applications. Plastic bottles are commonly made from polyethylene terephthalate (PET), which is the most recycled plastic in the world. The PET aerogels developed by the NUS-led research team using plastic bottle waste – a world's first – are soft, flexible, durable, extremely light and easy to handle. They also demonstrate superior thermal insulation and strong absorption capacity. These properties make them attractive for a wide range of applications, such as for heat and sound insulation in buildings, oil spill cleaning, and also as a lightweight lining for firefighter coats and carbon dioxide absorption masks that could be used during fire rescue operations and fire escape.

This pioneering work was achieved by a research team led by Associate Professor Hai Minh Duong and Professor Nhan Phan-Thien from the Department of Mechanical Engineering at NUS Faculty of Engineering. The technology to produce PET aerogels was developed in collaboration with Dr. Xiwen Zhang from the Singapore Institute of Manufacturing Technology (SIMTech) under the Agency for Science, Technology and Research (A*STAR).

Recycling plastic bottle waste

Plastic waste is toxic and non-biodegradable. Such waste often ends up in oceans and landfills, affecting marine life and causing problems such as groundwater contamination and land scarcity. Globally, the annual consumption of plastic bottles has been rising steadily, and it is expected to exceed half a trillion tons per year by 2021.

"Plastic bottle waste is one of the most common type of plastic waste and has detrimental effects on the environment. Our team has developed a simple, cost-effective and green method to convert plastic bottle waste into PET aerogels for many exciting uses. One plastic bottle can be recycled to..."
produce an A4-sized PET aerogel sheet. The fabrication technology is also easily scalable for mass production. In this way, we can help cut down the harmful environmental damage caused by plastic waste,” said Assoc Prof Duong.

**Versatile PET aerogels**

The research team took two years (from August 2016 to August 2018) to develop the technology to fabricate PET aerogels. This work was published in the scientific journal *Colloids and Surfaces A* in August 2018.

“Our PET aerogels are very versatile. We can give them different surface treatments to customise them for different applications. For instance, when incorporated with various methyl groups, the PET aerogels can absorb large amounts of oil very quickly. Based on our experiments, they perform up to seven times better than existing commercial sorbents, and are highly suitable for oil spill cleaning,” added Prof Nhan.

**Lighter and safer firefighter coats**

Another novel application is to harness the heat insulation property of the PET aerogels for fire safety applications.

Existing firefighter coats are bulky and they are often used with other breathing and safety equipment. This could take a toll on firefighters, especially during extended operations.

When coated with fire retardant chemicals, the novel lightweight PET aerogel demonstrates superior thermal resistance and stability. It can withstand temperatures of up to 620 degree Celsius – this is seven times higher than the thermal lining used in conventional firefighter coats, but weighs only about 10 per cent of the weight of conventional thermal lining. The soft and flexible nature of the PET aerogel also provides greater comfort.

Prof Nhan explained, “By adopting PET aerogels that are coated with fire retardants as a lining material, firefighter coats can be made much lighter, safer and cheaper. It is also possible to produce low-cost heat-resistant jackets for personal use.”

**2-in-1 mask that absorbs harmful carbon dioxide and dust particles**

When coated with an amine group, the PET aerogel can quickly absorb carbon dioxide from the environment. Its absorption capacity is comparable to materials used in gas masks, which are costly and bulky. To illustrate this application, the team embedded a thin layer of PET aerogel into a commercial fine particle mask to create a prototype mask that can absorb both dust particles and carbon dioxide effectively.

Prof Nhan said, "In highly urbanised countries like Singapore, the carbon dioxide absorption masks and heat-resistant jackets made using PET aerogels can be placed alongside fire extinguishers in high-rise buildings to provide added protection to civilians when they escape from a fire."

"Masks lined with amine-reinforced PET aerogels can also benefit people living in countries such as China, where air pollution and carbon emission are major concerns. Such masks can be easily produced, and can also potentially be made reusable," added Assoc Prof Duong.

NUS researchers are also looking into making simple surface modification to the PET aerogels for absorption of toxic gases such as carbon monoxide, which is the deadliest component of smoke.

In their earlier work, the research team had successfully converted paper and fashion waste into cellulose and cotton aerogels respectively. Coupled with this latest innovation involving the recycling of plastic bottle waste into aerogels, the NUS team was recently awarded first place in the Sustainable Technologies category of the 2018 Create the Future Design Contest by Tech Briefs.
