Researchers turn fashion waste into multifunctional material

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A research team led by Associate Professor Hai Minh Duong (left) and Professor Nhan Phan-Thien from the Department of Mechanical Engineering at National University of Singapore's Faculty of Engineering has devised a fast, cheap and green method to convert fashion waste into highly compressible and ultralight cotton aerogels. Credit: National University of Singapore

A research team from the National University of Singapore (NUS) Faculty of Engineering has devised a fast, cheap and green method to convert cotton-based fabric waste, such as unwanted clothing, into highly compressible and ultralight cotton aerogels. The researchers also demonstrated the application of this novel material to keep military water bottles cold and for effective control of rapid bleeding.

Aerogels are among the lightest materials in the world and are highly porous with strong absorption capacity and low thermal conductivity. These unique properties make aerogels highly suitable for applications in areas including oil-spill cleaning, personal care products such as diapers, and for heat and sound insulation. While aerogels were first created in the 1930s, they have not been widely adopted by industry due to high production costs. The NUS team has successfully pioneered the development of aerogels using cotton fibres harvested from textile waste.

Led by Associate Professor Hai Minh Duong and Professor Nhan Phan-Thien from the Department of Mechanical Engineering at NUS Faculty of Engineering, the research team discovered that the novel cotton aerogels can be easily compressed, and they can also very quickly recover up to 97 per cent of their original size when placed in water.

"This new eco-friendly cotton aerogel is a major improvement from the aerogel that our team had previously developed using paper waste. It is highly compressible, hence storage and transportation costs could be greatly reduced. Furthermore, these cotton aerogels can be fabricated within eight hours—this is nine times faster than our earlier invention, and about 20 times faster than current commercial fabrication processes. They are also stronger, making them more suitable for mass production. While we have demonstrated novel application of the cotton aerogels for effective haemorrhage control and heat insulation, we will continue to explore new functions for this advanced material," said Associate

Professor Duong.

Effective control of rapid bleeding

Haemorrhage, the rapid loss of blood, is caused by gunshot wounds or other deeply penetrating injuries, and can often be life-threatening. Haemorrhage control devices are used to exert internal pressure to stop bleeding and promote blood clotting.

Existing haemorrhage control devices comprise a syringe filled with small capsules of cellulose-based sponge coated with chitosan, a natural blood clotting agent derived from the shells of shrimp and other crustaceans. A syringe is inserted into the wound to release the capsule, which expands and applies pressure on the wound to stop the blood flow. However, the expansion and absorption rates of cellulose-based sponges are still relatively slow.

To address these limitations, the NUS researchers developed highly compressible hybrid cotton aerogel pellets that are more effective than cellulose-based sponges for treatment of deep haemorrhagic wounds. The pellets, comprising an optimal mix of cotton and cellulose aerogels coated with chitosan, are simple and cost effective to produce, and they can be easily integrated into a clinical syringe to be used for haemorrhage control. The cotton aerogel pellets are also biocompatible, hence they can be safely administered for treatment.

"Each cotton aerogel pellet can expand to 16 times its size in 4.5 seconds—larger and more than three times faster than existing cellulose-based sponges—while retaining their structural integrity. The unique morphology of the cotton aerogels allows for a larger absorption capacity, while the compressible nature enables the material to expand faster to exert pressure on the wound," added Duong.

The findings for this novel application were published in the scientific journal *Colloids and Surfaces A* in January 2018.

Heat insulation

A military canteen can typically hold one litre of water and maintain a cool temperature for about 30 minutes in a tropical climate. The NUS research team, in collaboration with DSO National Laboratories, developed a lightweight thermal jacket to maintain the temperature of ice slurry—crushed ice and liquid water—at 0.1 to 1.0 degree Celsius for more than four hours. The thermal jacket, which weighs about 200 grams, consists of a cotton aerogel layer embedded within commonly used fabrics to provide heat insulation.

The cotton aerogel-insulated military canteen offers better heat insulation performance compared to commercial insulated water bottles such as FLOE bottles, and is highly comparable to that of vacuum flasks. However, FLOE bottles and vacuum flasks are much heavier and more costly.

"The heat insulation property of the novel cotton aerogels can be applied to various consumer products, such as cooler bags to keep food items fresh. We also foresee tremendous potential for other high value applications, such as pipeline insulation and transportation of liquefied natural gas which needs to be stored at a low temperature," said Professor Nhan.

More information: Hai M. Duong et al, Compressed hybrid cotton aerogels for stopping liquid leakage, *Colloids and Surfaces A: Physicochemical and Engineering Aspects* (2017). DOI: 10.1016/j.colsurfa.2017.10.067

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