An ecofriendly technique to upcycle metal waste into multi-purpose aerogels

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These metal-based aerogels have high thermal and mechanical stability, and they could potentially be used as light-weight building materials and for growing cells for biomedical purposes. Credit: National University of Singapore

Metals are one of the most widely used materials in the world—they are

used in cookware, tools, electric appliances, electric wires, computer chips, jewelry and so on. With the growing demand for metal products, it is crucial to promote sustainable and environmentally-friendly methods of recycling metal waste to help reduce the environmental impact of using metals in the economy.

The conventional approaches for recycling metal waste are energy intensive and some of these methods also generate environmentally harmful by-products, such as ammonia and methane during aluminum recycling.

To address this challenge, a team of researchers from the National University of Singapore (NUS) has demonstrated a new eco-friendly technique to convert aluminum and magnesium waste into high-value, multi-functional aerogels. This upcycling method could be applied to all types of metal waste in power form, such as metal chips and electronic waste.

"Our approach is cheaper, does not produce any hazardous waste, consumes less energy and is more environmentally-friendly than conventional recycling methods for metal waste. The metal-based aerogels created using our unique fabrication technique have high thermal and mechanical stability. Hence, they are promising candidates for heat and sound insulation in harsh environments with high temperature or high mechanical impact. We are also exploring new uses for such aerogels, such as biomedical applications," explained research team leader Associate Professor Duong Hai-Minh, who is from the NUS Department of Mechanical Engineering.

This latest technological breakthrough achieved by Associated Professor Duong and his team builds upon their earlier successes in developing aerogels using different types of waste such as plastics, textiles, paper, pineapple leaves and other types of food and agricultural waste.

Simple, low-cost fabrication process

The NUS team has developed a simple fabrication process to create metal-based aerogels. Metal waste is first ground into powder and mixed with chemical crosslinkers. The mixture is heated in the oven, frozen and then freeze-dried to create the aerogel. The process may vary slightly depending on the metal waste involved. On average, it takes about one to three days to transform powdered metal waste into aerogels, compared to three to seven days using conventional methods of producing aerogels.

The simple process also means that metal-based aerogels can be produced at a much lower cost. Using the technique developed by the NUS team, a piece of metal-based aerogel that is 1 sqm in size and 1 cm thick costs less than S$10.50 to produce, half the price of commercially available silica aerogel.

Metal-based aerogels as versatile construction materials

Aerogels are highly absorbent, extremely light, and they have excellent thermal and sound insulation capabilities. In their earlier work, Assoc Prof Duong and his team had shown that the properties of aerogels can be altered by coating them with chemicals—for instance, they can become water repellent or fire resistant.

In their latest work, the NUS team has identified new exciting applications for metal-based aerogels. One promising application is to be used as light-weight construction materials.

"Our aluminum aerogel is 30 times lighter and insulates heat 21 times better than conventional concrete. When optical fibers are added during

the mixing stage, we can create translucent aluminum aerogels which, as building materials, can improve natural lighting, reduce energy consumption for lighting and illuminate dark or windowless areas. Translucent concrete can also be used to construct sidewalks and speed bumps that light up at night to improve safety for pedestrians and road traffic," Assoc Prof Duong added.

The translucent aluminum aerogels created by the NUS team is six times lighter, six times better in thermal insulation and 120 times cheaper compared to commercial translucent concrete (LiTraCon).

When coated with a chemical called methyltriethoxysilane (MTEOS), aluminum aerogels can repel water and becomes a self-cleaning construction material which allows dirt or debris to be easily washed away when it comes into contact with water.

Metal-based aerogels are also suitable as fire retardant boards, thermal insulation materials in buildings and piping systems, for absorption of airborne contaminants for indoor environments, and oil-spill cleaning.

Metal-based aerogels for cell cultivation

The NUS team is also looking at using aerogels for biomedical applications.

"We are currently working with a commercial partner to test our aluminum aerogels as microcarriers for cell cultivation. Microcarriers are micro-size beads for cells to anchor and grow. Our first trials were performed on stem cells, using a cell line commonly used for testing of drugs as well as cosmetics, and the results are very encouraging," explained Assoc Prof Duong.

To be used as microcarriers, aluminum aerogels are ground into powder

and added to the mixture of cells and growth media (including nutrients, antibiotics and growth supplements). The cells are cultivated at 37 degree Celsius in an incubator for 12 days. The microcarriers are then removed and the cells are harvested for various uses.

"After 12 days of incubation, our experiments obtained a yield of 70%. This is the first successful demonstration of growing cells using aerogels. We need to conduct more studies to optimize the culture conditions and address biocompatibility requirements. This is an exciting development that could open doors to a wider use of aerogels for non-conventional applications such as testing drugs and cosmetics, vaccine development and tissue engineering," Assoc Prof Duong explained.

The NUS team has recently published its work on creating aerogels using aluminum waste in the *Journal of Material Cycles and Waste Management* on 22 February 2021. Associated Professor Duong and his team are also in discussion with industry partners to commercialize the technology for fabricating metal-based aerogels.

In the next phase of their research, the NUS team is also looking at developing metal-based aerogels for applications that require extremely high temperature tolerance, such as for military applications.

More information: Thenappa S. Sp et al. Advanced fabrication and multi-properties of aluminum hydroxide aerogels from aluminum wastes, *Journal of Material Cycles and Waste Management* (2021). DOI: 10.1007/s10163-020-01169-1

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