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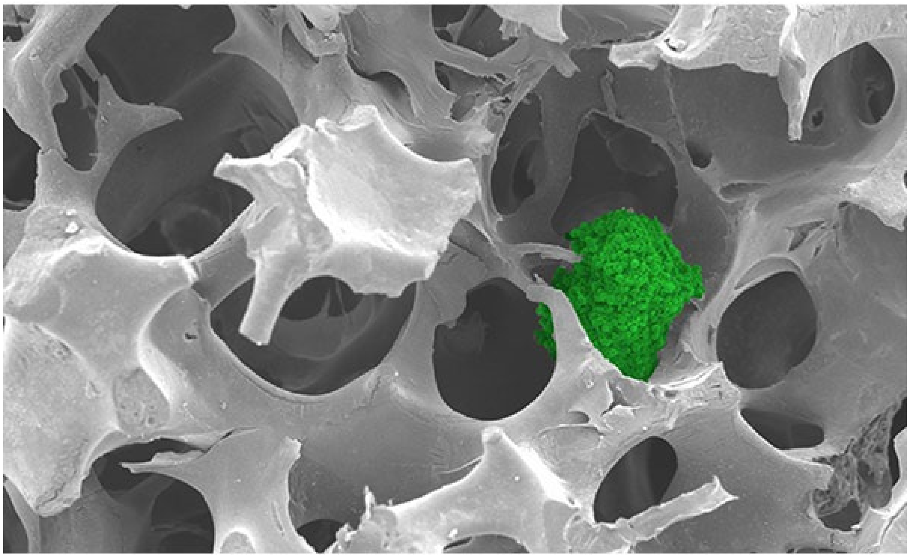
English translation

Living in a Plastic World: How to Tackle Plastic Pollution



Plastic pollution has emerged as one of the most pressing environmental problems with the increasing use of single-use plastics. As plastic is not biodegradable, it accumulates in the environment, disrupting habitats and natural processes. Additionally, millions of wild animals are ensnared by plastic waste every year.

When plastic breaks down, it releases toxic compounds that contaminate the environment. It also breaks down into small pieces of plastic called microplastics. Microplastics are now found all over the world and have been linked to serious health effects, such as metabolic disorders and organ damage.

Recycling plastic reduces the amount of plastic waste that would otherwise be left behind and conserves natural resources. However, only about 10% of plastic is currently recycled worldwide. This figure is low in part because recycling some types of plastic, such as e-waste and marine litter, is difficult. The chemical reactions that break down plastic into components that are easier to reuse are also energy-intensive.

From using e-waste plastic to grow cells to developing a more environmentally friendly way to break down plastic, researchers at NTU Singapore are solving some of the biggest challenges that stand in the way of plastic recycling and making strides in reducing plastic pollution.

Reusing e-waste plastic to grow “mini tumors” for lab analysis

Plastics make up a large portion of electronic waste (e-waste), and rapid technological advances and high consumer demand are driving their increasing use in electronics. According to a United Nations report, e-waste generation is growing five times faster than official recycling rates. In 2022, e-waste generated 17 million tonnes of plastic globally.

Single-use plastics are also widely used in research and healthcare applications, such as cell culture.

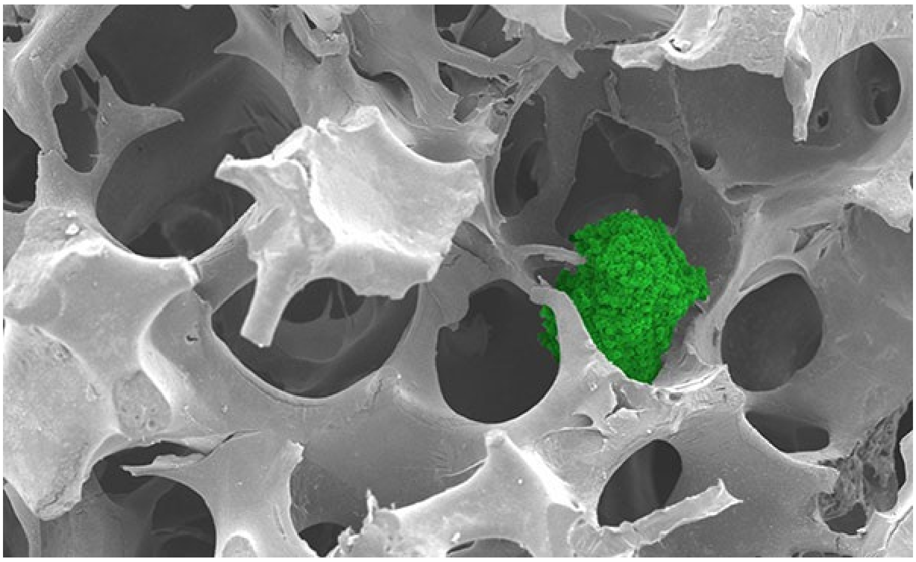
Acrylonitrile butadiene styrene (ABS) is a plastic commonly used in the housing of electronic devices such as keyboards and laptops. Repurposing plastics such as ABS for high-value biomedical applications could be an attractive strategy to effectively reduce plastic waste.

NTU scientists have developed a synthetic matrix for cell culture using ABS from discarded keyboards. The matrix is porous like a sponge and works as a support structure, providing a framework for cells to attach to and grow.

The matrix made from recycled electronic plastic. Credit: NTU Singapore.

The matrix can grow spherical clusters of cells, called tumor spheroids, that resemble actual tumors. Because of their three-dimensional shape, these “mini tumors” more accurately represent tumors than conventional cell cultures.

To make the matrix, the scientists dissolved scraps of plastic from discarded keyboards in an organic solvent, acetone, and poured the solution into a mold. The matrix supported the growth of breast, colorectal, and bone cancer spheroids. The tumor spheroids had properties similar to those grown with commercially available matrices and can be used for biomedical applications such as drug testing.



Tumor spheroid (green) growing in matrix. Credit: NTU Singapore.

"Our innovation not only offers a practical means to reuse e-waste plastic, but could also reduce the use of new plastics in the biomedical industry," said Prof Dalton Tay from NTU's School of Materials Science and Engineering, who led the research.

The research was reported in *Resources, Conservation & Recycling* in 2024.

Converting hard-to-recycle plastic waste into hydrogen and carbon additives for polymer foams

While some types of plastic can be reused in new products, other types of plastic are not as easy to recycle. Household plastics, packaging waste, and marine plastic litter recovered from the environment are all examples of plastic waste that are difficult to recycle. There are also limited economic benefits to treating mixed and contaminated plastics.

NTU researchers have experimented with using hard-to-recycle plastics as a source of solid carbon material for polymer foams. The researchers first obtained gas and oil by heating different types of plastic waste to high temperatures (600 degrees Celsius) in the absence of oxygen. Then the gas and oil were heated to over 1,000 degrees Celsius to break down the molecules into solid carbon and hydrogen. Solid carbon can be added to polymer foam to increase its strength and abrasion resistance for cushioning applications. The foam containing the synthesized solid carbon derived from plastic waste showed properties comparable to those of other conventional and carbon-based reinforcing materials available on the market. At the same time, the hydrogen produced could be collected and used as fuel.

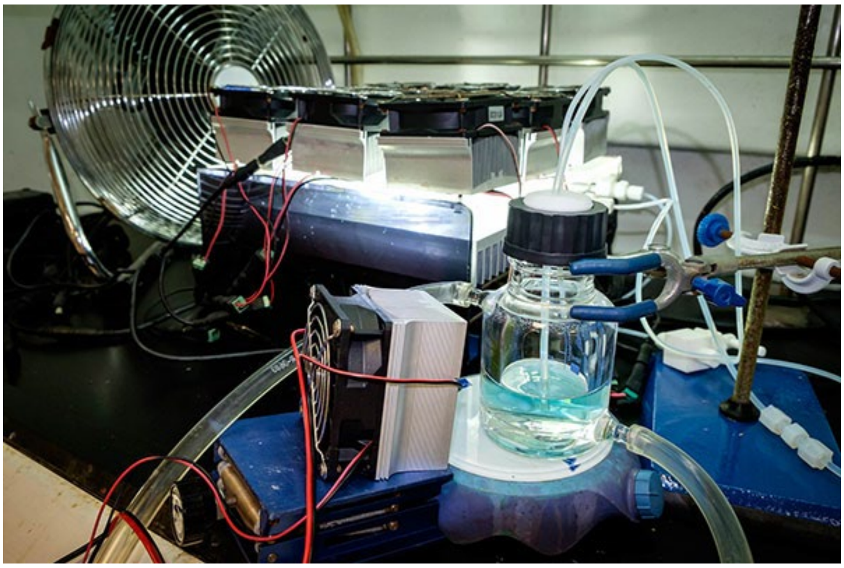
Published in the *Journal of Hazardous Materials* in 2024 , the research represents a milestone in finding a use for plastic waste that previously could not be recycled.

“We have developed a feasible approach to reuse difficult-to-recycle plastics, an important aspect of the circular economy,” said lead researcher Prof. Grzegorz Lisak from NTU’s School of Civil and Environmental Engineering.

A brilliant way to break down plastic into valuable components

Although plastics can be broken down by heating them to high temperatures, these processes are energy-intensive and generate greenhouse gases, contributing to global warming. To address the need for greener ways to break down plastics, NTU scientists have developed a process that can recycle most plastics into chemical compounds useful for energy storage. The reaction uses light-emitting diodes (LEDs) and a commercially available catalyst, and takes place at room temperature. It can break down a wide range of plastics, including polypropylene, polyethylene and polystyrene, all of which are commonly used in packaging and discarded as plastic waste.

Compared to traditional methods of recycling plastics, the process requires much less energy. First, the plastic is dissolved in an organic solvent called dichloromethane, which makes the plastic's polymer chains more accessible to the photocatalyst. The solution is then mixed with the catalyst and flowed through transparent tubes that are shone with LED light.



Experimental setup where dissolved plastic and vanadium catalyst solution are exposed to light, breaking down the plastic into useful compounds. Credit: NTU Singapore.

Light provides the initial energy to break carbon-carbon bonds in a two-step process with the help of a vanadium catalyst. The carbon-hydrogen bonds in the plastic are oxidized, making them less stable and more reactive. Next, the carbon-carbon bonds are broken. The resulting end products are compounds such as formic acid and benzoic acid, which can be used to make other chemicals used in fuel cells and liquid organic hydrogen carriers (LOHCs) – organic compounds that can absorb and release hydrogen through chemical reactions. LOHCs are being explored by the energy industry as a means of storing hydrogen.

According to Prof. Soo Han Sen of NTU's School of Chemistry, Chemical Engineering and Biotechnology, who led the study, the discovery not only provides a potential answer to the growing problem of plastic waste, but also reuses the carbon trapped in these plastics instead of releasing it into the atmosphere as greenhouse gases through incineration.

The method was published in the journal *Chem* in 2023.

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