It's not easy being green: While plastic is notoriously difficult to recycle, Natanel Jarach, an Azrieli Graduate Studies Fellow at the Hebrew University of Jerusalem, aims to change that by focusing on the polymers from which modern plastics are made.



By Dan Falk
Photographs by Marcelle Deichev

# BRINGING NEW LIFE TO OLD PLASTIC

**Most plastic products are like one-trick ponies. Newfangled polymers may give single-use plastics new purpose**

**We have a big plastic problem.** Actually, there are many problems throughout the plastic life cycle. Plastic production emits vast amounts of greenhouse gases. Most of the plastic in circulation is in single-use products that quickly make their way to landfill and beyond. And every year, up to 23 million tonnes of plastic waste leak into aquatic ecosystems. To top it off, plastic is notoriously difficult to recycle. But Natanel Jarach believes we may be able to do something about that last challenge.

"We live in the era of plastic," says Jarach, a PhD candidate and Azrieli Graduate Studies Fellow at the Institute of Chemistry at the Hebrew University of Jerusalem. "Look around you — everything is made of plastic, or polymers to be more precise." Polymers are natural or synthetic substances made of large molecules that are, in turn, composed of smaller, simpler chemical units known as monomers. "We can't live without them," he adds, "but they're causing damage to the environment because most of them are not degradable and can't even be recycled."

Born and raised in Israel, Jarach earned both his bachelor's and master's degrees from Shenkar College for Engineering, Design and Art in Ramat Gan, just east of Tel Aviv, where he specialized in polymeric material engineering. His current work, in Shlomo Magdassi's research group at the Hebrew University, is focused on developing plastics that can be used over and over again.

Traditionally, there have been two main approaches to recycling plastic: mechanical and chemical recycling. Mechanical recycling involves grinding and heating plastic to enable reprocessing. While it is a promising method, it can only process thermoplastics — plastics that are made of polymer chains held together by physical interactions, not chemical bonds. Thermoplastics become soft and mouldable when heated and harden upon cooling. The chemical recycling approach similarly only works with thermoplastics, primarily polyethylene terephthalate (PET), the kind of plastic used in beverage bottles.

In contrast to traditional recycling methods, the method Jarach and his colleagues are developing can work with both thermoplastics and thermosets. Thermosets are plastics that strengthen when cured, forming a chemically bonded network-like structure, such as epoxy and silicone. Unlike thermoplastics, once hardened, thermosets cannot be reheated and reshaped.

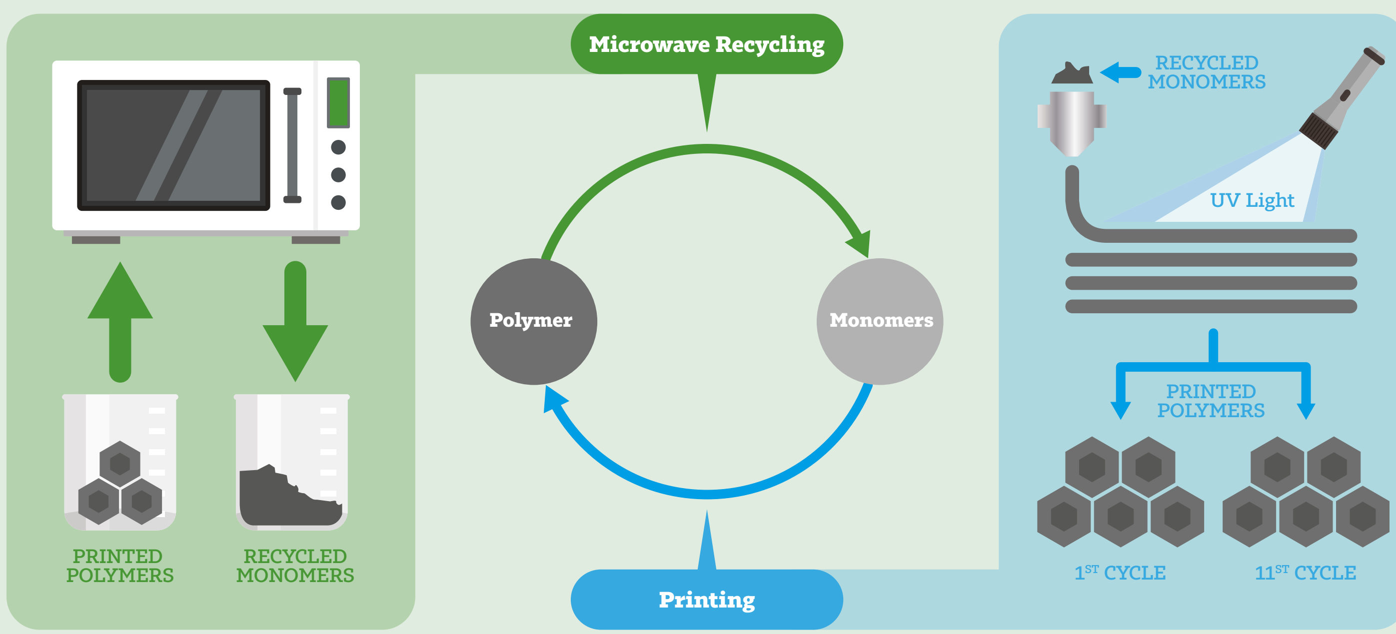
A key issue, Jarach notes, is that traditional recycling process causes degradation. What starts off as a rugged, versatile material may end up as a product with more limited use, a phenomenon known as downcycling. “Take a polypropylene plastic chair, which a lot of people have in the home,” says Jarach. “When you recycle it, you might end up with a fruit basket, because the degradation of the material is so significant.”

A typical example is the PET-type plastic used in bottles; it is cheap and light but diminishes in quality when recycled. In fact, studies suggest that only about 10 per cent of the plastics that have been produced so far have been recycled once, and only about 1 per cent have been recycled twice.

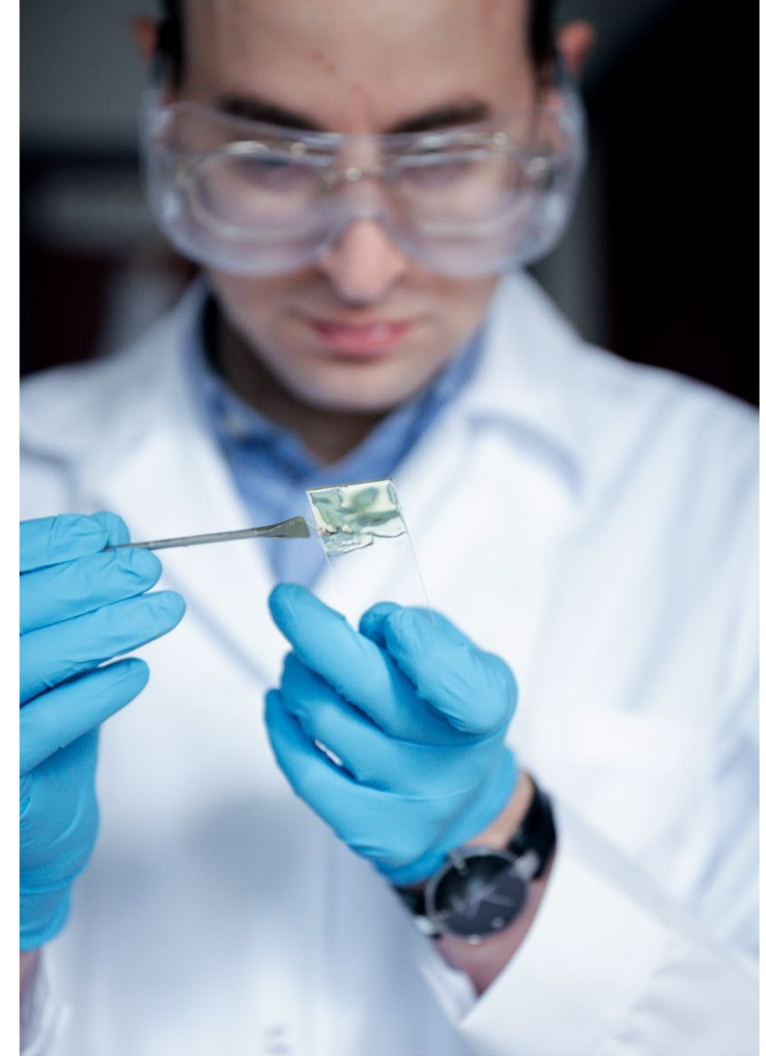
Part of the solution, Jarach says, is to focus on the actual polymers from which modern plastics are made. They can be produced via several different chemical reactions. One of the less traditional ones is known as cycloaddition, a process that Jarach developed that uses radiation of a specific wavelength for polymerization (when smaller chemical units come together to form polymers). But those reactions have typically involved ultraviolet C light, which is harmful to humans. One of Jarach’s goals was to see if the process of plastic production could be accomplished using a less dangerous type of radiation.

A key step was to introduce a catalyst — a metallic compound containing tin — to alter the chemical reaction. By incorporating tin into the compound that forms the foundation of plastic, visible light could be used instead of hazardous ultraviolet light. Initially, the compound is either a liquid or a semi-solid material. When tin is added, it interacts with light and triggers the hardening process, transforming the material into solid plastic. In addition to be safer, the use of visible light consumes less energy and accelerates the process, allowing it to unfold in as little as 10 minutes rather than hours or days.

A second breakthrough, this one involving the recycling of plastic, came when Jarach noticed that ordinary microwave radiation — exactly the type produced in our microwave ovens — can be used to re-assemble broken-down plastics into their original form without significant degradation. The process can be thought of as a loop. Using visible light, the monomers are printed into polymers — joined together like building blocks to create polymers, forming a solid material. Microwaves are then used to recycle the polymers back into monomers, and the cycle is repeated.




Jarach’s process of producing plastic, known as cycloaddition, can be thought of as a loop. At right, simple chemical units known as monomers are blasted with visible light and chemically bonded or “printed” into polymers (all plastics are polymers). At left, the polymers are broken down by microwave radiation into recycled monomers, which can then be printed back into polymers. Jarach has shown that polymers can be printed from monomers in numerous cycles without significant degradation.



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While traditional plastics will not disappear anytime soon, Jarach hopes the new wave of recyclable plastics based on techniques that he is helping develop will be adopted for specific applications, such as 3-D printing and adhesives.

The process has been patented but has not yet been adopted in an industrial setting. Jarach points to dentistry as an example of one industry where this new method can pay off. To make a tooth implant, a dentist uses a 3-D printer to create a mould, which is then filled with a ceramic material. The mould is then discarded, which Jarach sees as regrettable waste. “They use it for two minutes, and because it’s not recyclable, they throw it out,” he says. This is just one example of the many cases where industries that rely on 3-D printing can greatly cut down on waste by means of improved plastic recycling.

While Jarach’s two big innovations, focusing on the production and recycling of plastic, are on different ends of the life cycle of plastic, they both address the need to replace hazardous UV with safer alternatives. These techniques may work with other polymer-based materials besides plastics. For example, adhesives, which can be made from natural materials such as starch, or synthetic materials such as silicone, are, like plastics, everywhere in today’s world. And, like most plastics, they are not easy to recycle and often involve harmful chemicals in the recycling process.

One challenge in recycling adhesives, and all polymers for that matter, involves viscosity (roughly, a measure of how easy or difficult it is to “pour” the plastic in liquid form). Jarach and his team found that as he moved to materials with lower viscosity, the radiation time increased. “So we had to strike a balance,” he says. They experimented with different polymers made up of various monomers, zeroing in on materials that had the right chemical combinations and that could still be readily 3-D printed. “This has been a difficult problem to solve.”

Shlomo Magdassi, from the Institute of Chemistry at the Hebrew University (and Jarach’s co-supervisor, together with Hanna Dodiuk of Shenkar College), contrasts the challenge of recycling plastic with the much simpler process of recycling paper.

While different kinds of paper may have to be separated from one another before recycling, the procedure is more straightforward, he says. “You use water, and if it doesn’t work, a good option is to use more water,” he says. “I’m simplifying, of course, but that’s the idea. With plastic, you have to heat it to separate out the individual components, but when you do that, the material may lose its original physical properties.”

While the proportion of plastics that may one day be recyclable may never hit 100 per cent, he says there is no reason why the figure cannot be pushed ever upward.

Though traditional plastics will not disappear anytime soon, Jarach hopes these new recyclable plastics will be adopted for specific applications, ranging from 3-D printing to adhesives and beyond. “While I can’t predict precisely when our solution will reach the market, I sincerely hope it won’t take more than a few years,” he says. Jarach believes that the techniques he and his team are developing “will be part of the solution for the future of plastic. And let’s hope it’s a less polluted future.” ▲●■