RESEARCH PROFILE

PROFESSOR NIEN-HWA LINDA WANG

NEW SEPARATION TECHNOLOGIES TO RECYCLE POLYMER WASTES

OBJECTIVE

To develop new technologies for the separation of polycarbonates from electronic and polymer wastes, and the separation of flame retardants from polymers.

FUNDING

School of Chemical Engineering, Purdue University • Hugh and Edna Donnan Dissertation Fellowship • National Science Foundation (CBET 1403854) • SABIC Innovative Plastics

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NIEN-HWA LINDA WANG is the Maxine Spencer Nichols Professor of Chemical Engineering at Purdue University. She received her PhD in Chemical Engineering from the University of Minnesota in 1978. She is internationally known for her research contributions in separations, mass transfer, adsorption, multi-component chromatography and simulated moving bed technologies.

PURDUE UNIVERSITY

POLYCARBONATES ARE HARD and tough thermoplastics that display excellent mechanical properties and stability. Their structure makes them pliable, so they can be moulded and thermoformed. Their temperature resistance, impact resistance and optical properties make them one of the most widely used engineering polymers in the world.

THE DANGERS OF TOXIC WASTE

Alarmingly, more than one million tonnes of polycarbonates from electrical and electronic equipment waste are consigned to landfills each year. Disposal of this waste places a tremendous burden on the environment. In addition, there are millions of tonnes of polycarbonates and other polymers that do not make their way to landfills, and are instead found scattered across continents or oceans. Many of the polymers contain harmful chemicals that are released into the environment as they degrade. It is therefore extremely important for researchers to find means for reducing the environmental impacts associated with polymer wastes.

EFFICIENT RECOVERY OF HIGH-PURITY POLYCARBONATES AND OTHER POLYMERS

With that in mind, Professor Nien-Hwa Linda Wang has been conducting investigations that seek to curb the negative impacts of polymer wastes by recycling and reusing the polymers. Since waste from electronic applications of polycarbonates is the fastest growing polymer waste stream, Wang and her team decided to focus their attention on this issue. In one study, the researchers developed a room-temperature sequential extraction process using solvent mixtures that enabled the recovery of polycarbonates and other polymers from electronic waste. Importantly, the method consumes little energy, has a high yield (> 95 per cent), and produces high-purity (> 99 per cent) polymers with similar molecular weight distributions as the virgin polymers. The recovery cost is only about 30 per cent of the cost for synthesis of virgin polymers.

Recovering high-purity polymers with a high yield is difficult for various reasons, one of which is that polymer wastes are often complex mixtures with extremely variable compositions. The various polymers have similar physical properties and broad overlapping molecular weight distributions, which make their separation quite challenging. Since no single solvent was found to selectively dissolve polycarbonates in the waste, the team created new sequential extraction processes using multiple solvent mixtures. One major benefit is the reduction of environmental hazards associated with the polymer wastes found in landfills or oceans, by introducing financial incentives for collecting and recycling the wastes. Ultimately, Wang's aim is to develop various mixed-solvent extraction processes that would facilitate effective polymer recycling, thereby reducing the need for raw materials from petroleum and other sources, and significantly reducing CO_2 emissions.

DEVELOPING A SIZE-EXCLUSION SIMULATED MOVING BED

Wang's team has also developed an exciting technology for recovering flame retardants from the polymer materials. Each year, electronic polymer wastes containing more than 500,000 tonnes of organophosphorus flame retardants at low concentrations are sent to landfills. The researchers focused on developing a method to separate the flame retardants from the polymers. As environmental concerns have increased, many of the flame retardants that contain halogens are being replaced with safer organophosphorus flame retardants, which have less environmental impact.

While size-exclusion chromatography (SEC) is a well-known method of separation traditionally used for analytical applications, it is less efficient than simulated moving-bed chromatography (SMB) for large-scale separations. The team has developed new SMB technologies and a new process based on a low-cost SEC sorbent, which enables efficient recovery of high-purity flame retardants and a polymer from a side stream of the extraction process. Importantly, SEC-SMB takes up less floor space than SEC, requires lower labour costs and uses smaller amounts of solvents and sorbents for processing. Hence, the separation cost is an order of magnitude lower than those of conventional SEC processes for the same product purity and yield. The cost of recovery is less than 10 per cent of the purchase cost of the flame retardants.

The study revealed that optimised SEC-SMB processes could be an economically beneficial means of separating small molecules from polymers with high purity and high yield, thereby benefiting the environment without incurring high costs to the industry.