



DEALING WITH NUMBER



AND OTHER POLYMERIC CHALLENGES

Professor Marino Xanthos thinks a lot about plastics. That's in addition to assisting NJIT graduate students as associate provost for graduate studies, a post to which he was named in 2011. But to be more precise, Xanthos has spent most of his long career thinking about polymers, with plastics being a commercially indispensable group of synthetic polymers.

Xanthos is a leading researcher in the polymer field. And in a recent invited article written for *Science*, he discusses the special challenges of recycling polypropylene – designated Number 5 in the plastic industry's numerical nomenclature.

The yogurt you ate today? It was most likely packaged in polypropylene. Take a look at the number on the bottom of the container. Especially well-suited for food packaging, polypropylene has qualities that also make it the material of choice for consumer applications spanning textiles, stationery, automotive components and even banknotes.



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Some polypropylene, such as that used for automobile battery casings, is recycled in the U.S. However, while recycling other polypropylene products is technically feasible, it's not widely practiced. Recycling challenges include the cost of separating Number 5 products from the mix of plastics at waste-processing plants and certain chemical characteristics.

Polyethylene terephthalate (PET), Number 1, and high-density polyethylene (HDPE), Number 2, are recycled to a greater extent. A primary use for PET recycled from bottles and other packaging is to produce polyester fibers for carpeting, textiles and clothing. HDPE recovered from products like milk jugs and bags is reused in outdoor furniture, buckets, crates and plastic lumber.

But recovering any type of plastic from municipal waste for reuse is difficult and expensive, and only a small amount of the plastic in manufactured products is recycled relative to the volume produced. Still, as Xanthos writes, reuse of Number 5 plastic and its modified versions could increase as recycling becomes more environmentally urgent and economically attractive.

A WORD OF ADVICE: PLASTICS

The invitation to write the article about polypropylene for *Science* reflects the recognition Xanthos has achieved over a career of some four decades as an engineer and researcher working with polymers. A member of the Otto H. York Department of Chemical, Biological and Pharmaceutical Engineering, Xanthos came to NJIT in 1995 from Stevens Institute of Technology, where he was a research professor of chemical engineering.

Since joining NJIT, he has served as director of the Polymer Engineering Center and director of research at the Polymer Processing Institute (PPI). An independent corporation headquartered at NJIT, the PPI has research and pilot-testing capabilities that are an important real-world link between academia and industry. PPI initiatives encompass modification of polymers into high-value products for the medical, healthcare, automotive, electronics, construction and packaging industries.

Xanthos' career in polymers began as he completed a bachelor's degree in his native Greece and embarked on graduate study in Canada, where he earned a master's and PhD at the University of Toronto. He always had the practical bent of the engineer and found applied chemistry especially appealing. This inclination also led to his focus on polymers, long-chain molecules ubiquitous in natural and synthetic forms. Amber, cellulose, spider webs, wool and silk are some natural polymers. Our DNA is a polymer.

The extensive list of synthetic polymers includes the many types of plastics that have transformed our material culture since the middle of the 20th century. According to the U.S. Environmental Protection Agency, plastics comprised less than one percent of the nation's municipal solid-waste stream in 1960. Today, it's approximately twelve percent and growing. Plastics have replaced much of the steel in cars and wood in furniture. Structural components for aircraft are now manufactured from polymer composites, materials that are essentially special types of plastics.

As a young chemical engineer, Xanthos was intrigued by this polymeric transformation. It was a time when polymers were coming to the attention of consumers in more and more products – including the Chevrolet Corvette's all-fiberglass body. Speaking with a note of humor, Xanthos recalls the attention elicited by an iconic line from the 1960s film *The Graduate*. A well-meaning neighbor gives the young protagonist, who is very undecided about his direction in life, a single word of career advice: *plastics*.

Xanthos began his own professional involvement with plastics as manager of research and development at a Canadian subsidiary of Martin Marietta. There his responsibilities

included supervising the processing of mica, an additive and reinforcing component of plastics, and working on new applications. He transitioned to the academic world when he came to feel that ongoing corporate cutbacks might jeopardize his R&D position.

Continuing his relationship with industry in academia, Xanthos has been a technical advisor to firms such as AT&T, Colgate-Palmolive, Dow Corning, Elf-Atochem, ExxonMobil, Roche Diagnostics and Shell Chemical Company. At NJIT, he has helped to develop new applications for recycled plastics using more environmentally friendly processing, research funded by substantial grants. He holds five U.S. and two Canadian patents for work related to polymers that includes improving automotive finishes and reducing worker exposure to potentially harmful by-products.

Widely published, Xanthos is the author/editor of the authoritative *Reactive Extrusion: Principles and Practice, How to Manage Plastics Waste* and, more recently, *Functional Fillers for Plastics*. In 2003, he received NJIT's Harlan J. Perlis Research Award and was named a Fellow of the Society of Plastics Engineers (SPE). Of some 20,000 SPE members, only about one percent are accorded the distinction of Fellow. In 2010, he was honored with the Heinz List Award sponsored by LIST USA, an extrusion and polymer-reaction machinery manufacturer based in Charlotte, North Carolina.

OR ALL THE SEAS WITH BOTTLES

Xanthos has long been concerned about the environmental aspects of manufacturing plastics and their expanding use. While at Stevens, he had a grant from the U.S. Department of Energy to investigate how oil imports could be reduced by recycling plastic products, reflective of the era's nascent awareness of

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environmental as well as energy issues. It was also a time, he says, of well-intentioned but impractical environmental proposals.

“People wanted to recycle everything in sight. Someone even proposed recycling the adhesive from postage stamps. Today, interest in recycling seems to be more mature, more realistic with respect to what can be accomplished, what is economical. This includes making as many useful things as possible from recyclates.”

Xanthos agrees that the trend toward recycling more materials, including plastics, is part of a broader awareness of our global carbon footprint, and how we could all be impacted as individuals. “We see that climate change is happening. We see large areas of discarded plastic bottles and other items in the oceans, killing wildlife. Perhaps we are becoming aware of where the Earth is going and that we have to deal with big issues.”

Dealing with such issues, Xanthos goes on to say, involves more than a commitment to recycling. Life-cycle analysis is now an important part of the environmental equation.

Consider that yogurt container again. How much energy does it take to produce the raw material, to manufacture the container and transport it? How do these processes influence the environment, and can they be more efficient? Then there’s final disposal. These questions are even more challenging as society must decide how to deal with materially complex products like automobiles and buildings at the end of their usefulness.

When it comes to recycling, a great deal is up to the consumer. That’s especially true in the U.S., where there are fewer government mandates to recycle products we use every day compared to some other industrial nations.

The technology exists to recycle virtually all types of plastic and many other materials. But we will have to decide individually and collectively that it is worth the effort. It will depend on environmentally aware and cooperative consumers willing to sort more items before municipal collection. It will require government investment in the public resources needed and private-sector invest-

ment in the reuse of more recovered material for a greater range of products. Time will tell if the degree of social concern is adequate and the economics are right.

WORKING WITH THOSE TO FOLLOW

Xanthos has been an educator as well as a researcher throughout his academic career. He has mentored individuals studying for both master’s degrees and the PhD in chemical engineering, with Georgia Chouzouri ’07, Jin Uk Ha ’11, and Kuan-Yin Lin ’08 being among recent doctoral graduates. Chouzouri and Ha also completed their master’s at NJIT.

The paths followed by these alumni after graduation indicate the importance of their chemical engineering knowledge in diverse areas. Chouzouri is applying her skills in pharmaceuticals. “I was fortunate enough to work for my master’s and doctorate with Professor Xanthos as my adviser,” she says. “He taught me that chemical engineering is a field that can interact with various disciplines. Everybody can share ideas and incorporate them into a common goal, to give people a better quality of life.”

Ha is investigating materials that can reduce the weight of automobiles for a national research organization in Korea. He credits NJIT and Xanthos with really helping him to think critically and creatively, an ability he says is much needed in meeting his responsibilities as a project leader. Before joining 3M as a senior research engineer, Lin spent two years with the Polymer Processing Institute. He says that being introduced to the Society of Plastics Engineers by Xanthos and his PPI experience were particularly helpful academically and for building a career in industry.

Although Xanthos first worked mainly with graduate students pursuing degrees in chemical engineering, he found that engaging undergraduates in research offered additional satisfaction. Graduate students tend to have direction, he says. “They generally know what they want to do after leaving NJIT, like getting a better job. But it’s exciting to help undergraduates find their own direction, and perhaps become researchers.”

PLASTIC BY THE NUMBERS

In 1988, the Society of the Plastics Industry added a number to everyday life in the U.S. – the number that designates the type of plastic resin used to manufacture various types of packaging. Formally known as the Resin Identification Code (RIC), this voluntary system was introduced to facilitate sorting for possible recycling after collection. At present, more than half of U.S. states, including NJIT’s home state, have passed legislation mandating RIC use on certain bottles and other containers. The numbers in the code range from 1 to 7:

1. Polyethylene Terephthalate (PET)
2. High-density Polyethylene (HDPE)
3. Polyvinyl Chloride (PVC or vinyl)
4. Low-density Polyethylene (LDPE)
5. Polypropylene (PP)
6. Polystyrene (PS)
7. Other – Mixed Plastics

Over the years, helping young men and women find that direction has involved working with undergraduates in the Ronald E. McNair Post-baccalaureate Achievement Program. The program’s goal is to encourage students from groups underrepresented in science and technology to continue their studies and earn doctorates. Of her NJIT experience as a doctoral candidate, Chouzouri adds that she values the opportunity Xanthos gave her to mentor undergraduates in the McNair program.

EMPHASIZING THE POSITIVE

Asked to assess science education at the pre-college level, Xanthos offers the opinion that U.S. schools could do a better job of teaching the positive role of chemistry in daily life. Unlike the general view of biological science, he feels that too many people tend to think of “chemicals” in a negative way.

Xanthos would like young people to understand how chemists and chemical engineers are working for our benefit – taking on challenges such as finding innovative and economical ways to recycle the increasing amount of plastics we now discard. Including those yogurt containers. ■

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