The reincarnation of recycling

Professor Kim Ragaert discusses the problems surrounding post-industrial and post-consumer waste, the future of plastics recycling and how her research group is contributing to reducing the amount of plastic sent to landfill

Firstly, could you outline your background and what your research group is working on with regards to recycled polymer-based materials?

As a polymer processing engineer, I have been working with polymers for over a decade in extrusion and injection moulding, as well as 3D plotting. Our research group has quite an extensive industry network which includes many plastic-converting SMEs. We maintain a close relationship with them and much of our research is related to the scientific-technical challenges they are facing. Some years ago, questions about working with recycled polymers began to pop up quite frequently and in the meantime we have dedicated a research line to this topic.

What are the key aims and objectives of your research into polymer recycling processing?

Our research aims to provide the necessary scientific foundations for industry to be able to increase both the quality and quantity of recycled polymers used in their production. This includes insights into the material structures, properties and behaviour; compatibility of mixed streams; development of processing methods; and creation of specific design guidelines for working with recycled polymers.

Can you explain the differences in the quality of post-industrial and post-consumer waste, and the problems associated with recycling the latter?

Post-industrial waste is recovered during the production of polymer products in the factory. This typically includes rejected products, cutting edges and sprue bushings, to name a few. The great advantage of these materials is that companies know exactly what they are made of and what is inside, and the materials themselves are not contaminated by organic materials as in the case of yoghurt pots, drink bottles or other plastics due to mixed plastics collection or dirt.

Many companies regrind their post-industrial waste themselves and add it in small percentages to their own products. This is not possible for post-industrial polymer waste which has already been irrevocably mixed during the process, like pressed carpet fibre. Except for the latter, mixed streams, there isn't much work left for science in post-industrial waste, as they are often high-quality materials, composed of a single polymer type and of relatively pure composition.

Post-consumer waste is a lot more complicated. It is hard to know the exact composition of a material and, moreover, composition and overall quality vary depending on the batch. First of all, this waste can be contaminated by organic materials, paper and glue from labels and even wood. Secondly, to consumers plastic is plastic. Disposing foil materials separately is a message that can be taken up, but for the so-called 'hard plastics', many different kinds of polymers are disposed of together, if they are kept separate from household trash at all. This means that sorting is considerably intensive and there will always be contamination from other polymers.

Europe has set a target to have zero plastics in landfill by 2020. With current progress in research on polymer recycling, do you think this goal can realistically be achieved?

It's definitely a hard target and its achievement depends on so much more than developments in science and technology alone. On the side of collection, we also need policy makers, who are the main drivers in how post-consumer waste is separated and collected, and the consumer themselves (who must be convinced to follow these policies). On the side of production, SMEs considering making the changeover to using recycled materials should be supported in making the necessary investments. Finally, we again need individual consumers to overcome the misconception that a product of recycled material is inferior. If they don't buy it, the companies needn't make it. Luckily, more and more proof-of-concept cases are emerging, promoting the use of recycled polymers.

But yes, when all of these actors sufficiently pull together, I think we can do it. Projections show that when compared to a business-as-usual scenario, this would potentially save us 80 million tonnes of plastic waste, which is the same as 1 billion barrels of oil or €70 billion.

Do you collaborate with commercial or academic partners?

In addition to our extensive collaborations with companies (both SMEs and multinational companies, individual or in bigger consortia), we also collaborate with quite a few other research groups in the fields of polymer processing, polymer characterisation and product design. These collaborations can be short consulting assignments, more extensive innovation projects with companies, fundamental research projects with universities, and joint PhD projects with both industry and academic institutions.

From **new** to old to **new** again

A team at the Centre for Polymer and Material Technologies in **Ghent University**, Belgium, is researching ways to improve and increase the use of recycled polymers by industry and consumers

PLASTIC IS THE general term for a wide range of synthetic and semi-synthetic materials that modern society uses or comes into contact with on a daily basis. Plastics are ubiquitous nowadays, used across the globe in packaging, building and construction, transportation, electronics, agriculture, medicine and health, as well as sport and leisure.

In 2012, approximately 240 million tonnes of plastic were produced globally, 20.4 per cent of it manufactured in Europe. Much of this could be recycled, but instead it often ends up in landfill sites and can take up to 500 years to decompose. Further to this, 4 per cent of the world's oil is used to make plastics, with a further 3-4 per cent being used to provide energy for their production.

Aside from the fact that this is harmful to the environment, plastics are a valuable resource and could be reused rather than thrown away. Recycling is one of the most important actions currently available to reduce the negative impacts of both the production and use of plastics. If plastics are to continue to play a major role in delivering and sustaining the quality, comfort and safety of modern lifestyles, then a multifaceted approach to recycling is required. Consumers will need to become more proficient at sorting their waste and governments will need to improve logistical aspects of collecting and recycling. Industry will also have to increase the use of recycled plastics in their products, and recycled products must be made more attractive to customers.

THE POLYOLEFIN CONUNDRUM

Research by Professor Kim Ragaert and her colleagues at the Centre for Polymer and Material Technologies at Ghent University, Belgium, could have a role to play in improving plastic conversion in industry. One of the main foci of Ragaert's current research is polyolefins, a class of polymers which mostly comprises polyethylene and polypropylene; two of the most common types of plastic used. Together, they make up 50 per cent of all plastic products and account for more than 47 per cent of Western Europe's total plastic consumption per annum. However, recycling these plastics is not as routine as it should be.

In recycling processing centres, these two plastics are often found mixed together as they are hard to separate using optical or gravimetrical techniques. The resulting mix of plastics is often referred to as mixed polyolefins. Many mixed polyolefin materials are available on the market and are usually cheaper than mono-streams of relatively pure polyethylene or polypropylene. However, polyethylene and polypropylene do not mix in the melt phase of recycling, which is required for processing the material into new products. This leads to a variety of problems, including reduced mechanical properties like impact resistance. The same can be said for any mix of different polymers, hence Ragaert and her team are looking at ways to improve the properties of recycled mixed polymers so that they are more likely to be used by industry and consumers.

TESTING THE PROPERTIES OF PLASTICS

Taking the drawbacks of using recycled plastics into account, the Ghent researchers have been studying both mixed polyolefins recycling as well as other mixed polymer streams such as polypropylene and polyethylene terephthalate or polyethylene and polyethylene terephthalate. They have also been looking at polyamide waste from the textile sector, otherwise known as nylon, as well as investigating the possibilities of recycling very specific polymers produced by the group's industrial partners, which can be contaminated, filled or modified in a unique way.

The team uses many different techniques to examine polymer properties. Differential scanning calorimetry is one method they use to determine transformation temperatures (temperatures at which the material changes phase). Each different polymer has a distinct melting temperature and, by observing the different melting points, the researchers can gain insight into which polymers are present in the mix. Infrared measurements are also taken, as well as conventional tensile, flexural and impact tests. Finally, tests such as melt flow rate are undertaken to give the team an indication of the degree a particular polymer will flow in the melt phase of recycling and how it can be processed.

PUTTING TECHNIQUES INTO PRACTICE

In particular, Ragaert and her group have been working on overcoming the immiscibility of melted polymers; for example, polyethylene and polypropylene. "The most straightforward approach is to add materials which serve as compatibilisers," explains Ragaert. These compounds include chemical structures that have an affinity for two different polymers, forming a chemical 'bridge' between both components and allowing them to mix.

However, under some circumstances Ragaert highlights that this phase separation could be considered as an advantage of the mixed

POLYMER RECYCLING

OBJECTIVE

To provide scientific support to increase both the quality and quantity of the industrial use of recycled polymer-based materials. This includes compatibilising mixed streams, developing polymer-polymer composites, drafting design criteria for products from recycled polymers and improving their mechanical properties.

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KIM RAGAERT obtained her PhD in Polymer Engineering in 2011. She lectures on materials science and polymer processing at Ghent University's Faculty of Engineering and Architecture, where she has recently been appointed Assistant Professor in the domain of 'Sustainable Use and Recycling of Polymers and Composites'.

material: "Conceivably, a more rigid plastic in the mixed material (eg. polyethylene terephthalate) could be seen as a strengthening phase to the matrix of the more malleable plastic (eg. polypropylene)". This is the concept behind polymer-polymer composites, which have modified properties from single polymer recycled plastics. These include nanocomposites, a class of materials that contain nanoscale particles, and form a separate strand of Ragaert's polymer research.

A DESIGN FOR LIFE

It is clear that Ragaert and her team have an array of approaches when it comes to researching how to better recycle plastics, but they also look at product design, which includes both design for and from recycling. This involves taking the recyclability of a product and its materials into account from the moment it begins to be designed, as well as ensuring that the product is specifically designed so that it can be produced from recycled polymers rather than newly produced plastics.

"By exploring both tracks of working with mixed streams of polymers – compatibilisation and making polymer-polymer composites – as well as aspects like processing parameters and product design, our work will expand the applicability of mixed polymer waste and improve the quality of products manufactured from them," details Ragaert. "This will make the materials more attractive and more accessible to SME plastic converters."

WHAT IS AHEAD FOR PLASTICS RECYCLING?

In terms of the future of plastics recycling and its use by industry, Ragaert believes that her work is just the beginning: "I feel that sorting methods will improve, yielding both a higher quality and quantity of recycled polymer waste. And from our side of polymer processing, I feel that we will continue to improve the types of materials we can effectively process and the products we can manufacture with them".

CPMT GROUP

The Centre for Polymer and Material Technologies (CPMT) is a research group of the Faculty of Engineering and Architecture at Ghent University, headed by Professor Ludwig Cardon. Its main research lines include processing of advanced thermoplastic materials (biobased, biomedical, technical, (nano-)composites), advanced mould making (hybrid moulds, conformal cooling), additive manufacturing and recycling of polymers.

The group has extensive equipment and experience concerning extrusion (single, twin and multilayer), injection moulding (including micromoulding), 3D printing and characterisation (mechanical and physicochemical) of thermoplastic polymers. They often collaborate with industry or other research institutes on both applied and fundamental research projects.

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