As the name suggests, compatibilisers are an essential group of additives that can form chemical linkages between materials that are normally incompatible. Used in plastics compounding for some time to improve physical and mechanical properties, as well as processability, compatibilisers are now receiving significantly more attention as the importance of the circular economy and the need to re-use mixed polymer streams continues to grow in importance.

The market is growing for materials that can compatibilise mixed resin streams, according to ExxonMobil. “Resins, or compounds that are made up of these resins, can be used to compatibilise recycled plastics whether it is post-consumer recycled (PCR) or even post-industrial recycled (PIR),” says Pam Cadile, Market Developer. “The continual growth is due to brand owners pushing to use these recycled plastics in their packaging products for consumer products, industrial container and material handling supplies.”

There are a number of factors that need to be considered when using compatibilisers for recycled plastics, says Cadile. These include how contaminated the waste stream is. For example, is the waste material 100% of a particular resin type, such as polypropylene, polyamide or polyethylene? If so, data proof on the certificate of quality, for example FTIR (Fourier-transform Infrared Spectroscopy) or DSC (Dynamic Scanning Calorimetry), for the specific batch is required. However, most waste resins are a mixed stream, so any one resin type is contaminated. Contamination can be of another resin or a filler, such as colourant, calcium carbonate, talc or even paper, and can affect the processing or performance properties.

For compounds produced from recycled plastics, another consideration is whether the compounding has already added a compatibiliser. “If so, will the supplier share what they have done with you so you can understand if the compatibiliser has upgraded the resin at all and what processing or performance advantages are the result,” says Cadile. “They may be using a product that is not meeting your processing or performance needs at all and you need something specific for the overall system.”

It is important to know the quality of a compatibiliser in a recycled compound. She says: “We are finding that many compounders use an off-spec plastomer. When one purchases off-spec resins they are introducing another variable into the
compound that is not under control. It is necessary to know if off-spec resins are being added as it is no longer 100% recycled resin and the off-spec nature of the resin is giving variability from lot to lot. Some of these plastomers are also not as easy to mix into the recycled resin stream and the more energy that is put into the compounding step could be causing more degradation, which results in low molecular weight species or crosslinking when mixing polyethylenes that result in gels or lower melt flow rates.”

It is also necessary to know how the compounder has mixed in the compatibiliser. “It is found in many cases that single screw extruders are used before repelletisation,” adds Cadile. “If a compatibiliser is added, this single screw may not fully disperse the additive and properly mix it, which may result in pellet to pellet inconsistency. Twin screw extruders help to ensure compatibilisers are mixed thoroughly and convertors do not see as much variation when they process.”

Brand owners are making changes to facilitate increased use of recycled materials. But some consumers are concerned that not all of the plastics they are collecting is being recycled but instead is going into landfills, adds Cadile.

In order to address these issues being faced by recyclers and end users currently, ExxonMobil has introduced a number of products for use in recycled content streams – Exact plastomers, Excelor polymers and Vistamaxx performance polymers. The choice of product depends on what needs to be achieved, and with Vistamaxx it is possible to compound with less shear and lower processing temperatures. It is amorphous so it can incorporate the low molecular weight species that are produced after working the material multiple times and is compatible with polyethylene and polypropylene.

ExxonMobil says its compatibilisers enable the use of lower quality, lower cost recycled content sources. Vistamaxx polymers effectively compatibilise at low loading levels, increase process consistency and better overcome variability in melt flow characteristics. The melt flow of the recycled content stream can be tailored to the process requirements of the end-use application. Incorporating recycled content materials often reduces the toughness of a product, but adding small amounts of Vistamaxx restores toughness.

Vistamaxx 6102, Vistamaxx 6202 and Vistamaxx 6502 have been developed for customers with mixed polyolefin recycling streams. The company says that by adding 5-10% of Vistamaxx polymers to a blow moulded PCR HDPE the environmental stress cracking resistance of bottles containing recycled content can be improved. The addition of 10% Vistamaxx 6102 to PCR HDPE contaminated with around 20% PP delivers 250% higher impact strength. The addition of 5% Vistamaxx 6202 to PCR PP contaminated with around 30% PE delivers 50% higher impact strength and approaches virgin ICP impact performance. Adding 5% Vistamaxx 6102 to a film structure based on PCR PE contaminated with around 15% PP delivers 40% higher dart impact and 20% higher tear resistance.

ExxonMobil was recently involved with Chilean company Atando Cabos to turn discarded fishing ropes into high-quality end products in a project that brought environmental, social and financial benefits. Atando Cabos wanted to recycle these ropes contaminating the delicate ecosystem of Patagonia, but found they were made of incompatible plastics that could not be separated. Vistamaxx products enable conversion of PE and PP waste into durable products such as these crates produced by Atando Cabos.

Above: Mixed packaging waste bales usually comprise both PP and PE containers

Above: ExxonMobil says the use of its Vistamaxx products enables conversion of PE and PP waste into durable products such as these crates produced by Atando Cabos
Bright Green Plastics looks ahead

UK-based Bright Green Plastics has new ownership and is looking to continue the success of its business in compatibilised recycled polyolefin compounds.

The company, based in Castleford, West Yorkshire, was established in 1992 as a subsidiary of packaging producer Linpac. It was owned by Imerys until late 2019 when it was acquired by the investment group AIAC. The recycler rebranded from Imerplast to Bright Green Plastics to signify the start of a new era for the company.

The mixed plastics waste recycled at the Castleford facility includes PP items (such as pots, trays, tubs, paint pots, food buckets and storage boxes) and HDPE items (household cleaning bottles, water pipes and industrial ducting). PP and PE materials are recompounded with the company’s own BrightFusion mineral compatibiliser. This enables the recycled compounds to be used in high quality products - see article in Plastics Recycling World March-April 2019 issue about paint pots made using the company’s PE-PP compound.

In May, Bibby Financial Services provided a £6m funding facility to Bright Green Plastic to support the company’s growth goals. Steve Spencer, Director at Bright Green Plastics, said: “The new funding from BFS will provide the business with the working capital needed to continue with our expansion into Europe. We were impressed by the level of flexibility that BFS were able offer, particularly in the current climate. We’re very happy to partner with the team as we take the business into the next phase of growth.”

Bright Green Plastics, based in Castleford, UK, changed ownership in late 2019

Above: Bright Green Plastics looks ahead

performance polymers were used to compatibilise PE and PP and allow them to mix in the melt, removing the need for separation. They also improved product quality for high-value applications such as crates (see Plastics Recycling World, November-December 2019).

Compatibilisers have a key role to play in advancing the use of recycled plastics in the circular economy, says Kraton. “Mixed plastics streams continue to be a challenge for the recycling industry” says Bob Hall, Senior Director, Global Marketing. “Due to the poor processability of mixed streams, it often ends up in the landfill. A major gap in current offerings is a universal, cost-efficient compatibilisation solution that could work across multiple recycling waste streams – not just polyolefinic recycling streams.”

He says important issues to consider include formulation cost efficiency and product performance. “Post-consumer resins are already at a cost disadvantage compared with virgin plastics, where the spread varies by region and by resin. The price pressure is evident, especially at times when the price of oil is below $50 per barrel. In order to address the economics of plastics recycling, it is critical to understand the value added by compatibilisation throughout the value chain versus the additional formulation cost. Essentially, it is about the value that can be captured by recyclers, compounders or converters through upcycling compared to the alternative of landfilling the mixed streams.”

Despite growing consumer interest about plastic waste issues, consumer willingness to pay a premium has its limits, he says. This in turn drives the brand owners’ position on where and how to use recyclates.

“There is also the expense of achieving a completely pure recycled product cycle with equivalent quality as virgin resins, which is often well beyond what is commercially feasible. The use of compatibilisers allows slightly impure recycled products to be reused while enabling it to perform like a homogeneous resin. Achieving this would allow for lower cost in the use of recycled resin.”

Kraton adds that the plastics recycling industry is a highly dynamic space with rapid changes driven by multiple factors. These include consumer preferences, regulatory changes, brand owners’ approach to product design, innovation throughout the plastic value chain and the influence of industry associations that will further impact the needs for recycling compatibilisers. Economics will be a key factor given the post-consumer recycling stream, where in some cases, chemical recycling can be a better alternative to mechanical recycling.
However, there are multiple mixed streams with incompatible resins that lack mechanical recycling solutions, besides packaging applications, says Hall. “Consumer durable products is an example. Due to the multi-material product design approach by the application's performance requirements, the combination of different materials used to make the end product poses recyclability challenges. Kraton’s R&D team is collaborating with the plastic value chain to develop a sustainable solution to these problems. For recycling plastics, product performance and formulation cost efficiency are the key priorities.”

Kraton recently launched the CirKular+ product line, which is specifically engineered to enable plastics upcycling and circularity across a wide range of end-use applications, with the first CirKular+ compatibiliser series being a functionalised styrene-ethylene-butylene-styrene (SEBS). “CirKular+ solutions offer versatile multi-resin compatibilisation and performance enhancement in wide range of applications including PCR and industrial plastic recycling streams, bioplastics such as PLA, and flexible product design using a combination of virgin and recycled plastic materials,” says Hall.

The CirKular+ universal compatibiliser series has been created to help increase homogeneity of contaminated waste streams across different resins including polyolefins, PET, ABS, PS and PA. It is also used as a performance enhancement modifier for PLA. Hall says its efficiency results in cost-effective performance at low dosage and is fully reprocessable.

“Plastic resins modified with CirKular+ have shown better reusability after undergoing multiple cycles of mechanical recycling due to minimal degradation of physical properties in comparison to unmodified resins,” he says. “Our solutions offer excellent adhesion by reducing phase separation of recyclates during processing, which delivers universal compatibilisation of previously incompatible materials and difficult-to-recycle engineering polymers. Resin modification with our additives improves impact resistance and increases end-product reusability at the end-of-life.”

Ampacet has introduced Revive 962 E, a compatibiliser masterbatch that enables recycling of multi-material packaging made of polyolefin and technical polymer components into quality film applications. The company says that while most flexible, mono-material packaging films – PE and PP – can be easily mechanically recycled, recycling multi-material packaging structures presents challenges. Food products, for example, may require multi-material packaging to provide gas barrier functionality that protects packaged food, extends shelf life and reduces food waste. Distributing the polyolefin recycling stream with non-polyolefin components must be avoided when recycling multi-material packaging films in order to ensure a level of quality that allows upcycling into new packaging.

According to Ampacet, Revive 962 E offers a sustainable solution for multi-material polyolefin barrier packaging that enables use of reclaimed material in quality film applications. Revive 962 E has been specifically designed for in-house recycling of polyolefin EVOH-based barrier film industrial scraps for reuse in the original film structure, when preservation of optical and mechanical properties is required. Revive 962 E is claimed to improve the homogeneity and transparency of reprocessed polymer blends. Mechanical properties of films made with these blends are similar to the main base polymer, says Ampacet.

The approach of Kenrich Petrochemicals to post-consumer recycling processes comprises repolymerisation and compatibilisation of thermoplastics by using titanate ester catalysts. According to President Salvatore J Monte, the extruder can become a reactor for coupling and catalysis of all the materials in the recyclate fed into the hopper. He claims that if Ziegler, Natta and Kaminisky used titanium and aluminium catalysts to produce addition polymers, titanate catalysts are used to produce condensation polymers, and heteroatom
titanate coupling agents compatibilise fillers with polymers, then why cannot titanate and aluminium be used as a catalyst and coupling agent for compatibilising the fillers and polymers (both addition and condensation) used in plastics to be recycled.

“Current plastic recycling and sustainability goals are limited by the intrinsic incompatibility of many polymers and the negative effect of fillers and impurities on end-product properties,” says Monte. “This requires a high degree of expensive sorting, separating and cleaning. Another barrier is the melt processing of polymers that causes chain scissoring resulting in recycled and regrind materials having inferior properties compared to virgin.”

He says current compatibilisers offered to recyclers are based on co-polymers or maleic anhydride modified polymers and both have drawbacks, such as the requirement for sorting mixed polymer waste streams. The Kenrich approach to compatibilisation is completely different. Monte says: “We use either a monoalkoxy or neoalkoxy titanate in combination with $\text{Al}_2\text{SiO}_5$ mixed metal catalyst in powder and pellet forms for in-situ macromolecular repolymerisation and copolymerisation in the melt. This in-situ organo-metallic catalysis results in polymer compatibilisation as the neoalkoxy titanate also proton coordinates with inorganic fillers and organic particulates to couple and compatibilise the dissimilar interfaces at the nano-atomic level, thus reducing the need for expensive sorting of materials in recycled plastics.”

He continues: “In addition, many compounders are schooled in the art of silane coupling agents, limiting filler and organic interface coupling to hydroxyl bearing materials such as silica and fibreglass. This categorises fillers such as CaCO$_3$, BaSO$_4$, carbon black and organics such as oils as contaminants. In addition, silane art requires knowledge of hydrolysis mechanisms and techniques usually outside the realm of melt recycling compounders. Nano-titanium technology applied at the interface of dissimilar materials can be the ‘Holy Grail’ of plastics recycling.”

CLICK ON THE LINKS FOR MORE INFORMATION:
- www.exxonmobilchemical.com
- www.kraton.com
- www.ampacet.com
- www.4kenrich.com
- https://brightgreenplastics.com

Above: Kenrich Petrochemicals’ approach to compatibilising PP and PE uses titanate ester catalysts

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