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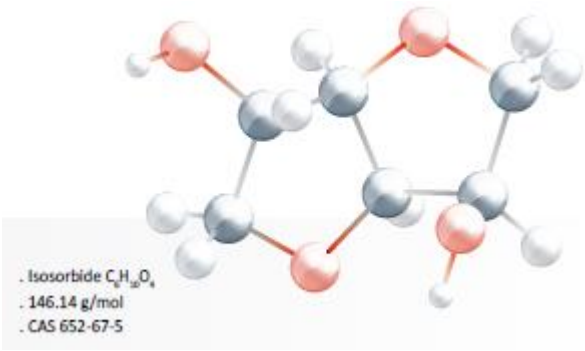
Introducing isosorbide: a sustainable, safe, high performance, plant-based feedstock for packaging.

Though often labelled as 'the problem' plastic packaging has the potential to become the solution with estimates suggesting that switching plastic out for alternatives, such as aluminium and glass, could result in a 2.7 fold increase in greenhouse gas emissions.[1] Establishing a circular economy, in which plastics are efficiently recycled and reused, is essential but so too is the development of new, sustainable feedstocks and high performance materials. Step forward isosorbide. Perfectly safe and produced from an annually renewable feedstock isosorbide has exciting potential for a range of packaging applications.

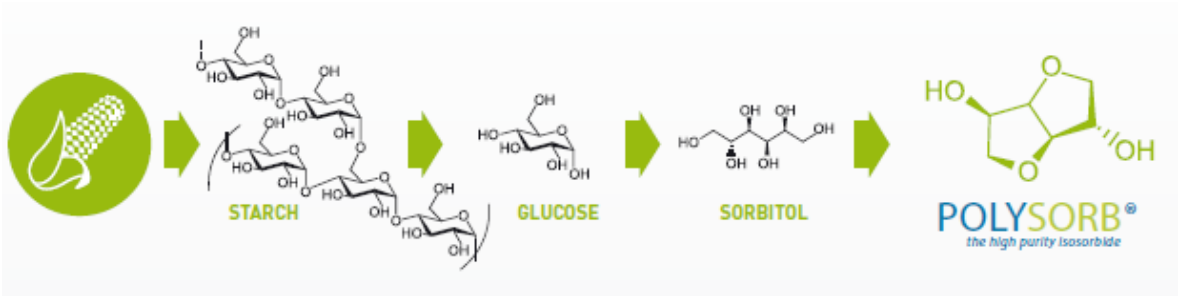
What is isosorbide and how is it made?

Isosorbide is a plant starch-derived bicyclic diol with rich functionality for a range of applications in the packaging, coating, adhesives, sealents and elastomers (CASE), and automotive sectors.



Isosorbide is a bicyclic diol derived from plant starch.

The schematic below illustrates how isosorbide is made. Starch from annually renewable feedstocks is hydrolysed to produce glucose which is then converted to sorbitol and on to isosorbide by hydrogenation. Over the last two decades, Roquette, the world's leading manufacturer of isosorbide has refined and optimised this manufacturing route to produce stable, high purity isosorbide in industrial quantities. The company's flagship plant produces isosorbide of three different grades, each tailored to specific industrial applications.



POLYSORB® ISOSORBIDE A FULL RANGE WITH OUTSTANDING PROPERTIES

SPECIFICATIONS	POLYSORB® PA	POLYSORB® LP	POLYSORB® PSA
Application	all	polyesters	Polycarbonate, polyurethane
Color	white	colorless	white
Type	pellets	liquid	pellets
Purity (% DS-HPLC)	>=99.5	>=99.5	>=99.5
Water content	-	20.0% max.	-
pH (40% in water)	6.5-8.5	6.5-8.5	8.0-9.0

Isosorbide is industrially manufactured from renewable plant feedstocks in a series of different grades.

As a plant-based, sustainable feedstock with a carbon footprint of just 0.09 kg CO_2/kg of product, isosorbide is an attractive substitute for monomers such as bisphenol A, which has a carbon footprint around 60 times higher.

However, impressive environmental credentials are just the start.

Isosorbide is:

- Non-toxic
- Non-carginogenic
- Non-endocrine disruptor
- REACH compliant
- Suitable for food contact and for the manufacture of cosmetics and pharmaceuticals.

These attributes make the performance benefits of isosorbide of interest and value in a diverse range of applications.

What are the properties of isosorbide and how can it be used?

Isosorbide can be incorporated alongside other monomers to modify the properties of, for example, polyethylene terephthalate (PET), polycarbonates (PC), polyurethanes (PU) and epoxy resins. When used in this way it can enhance:

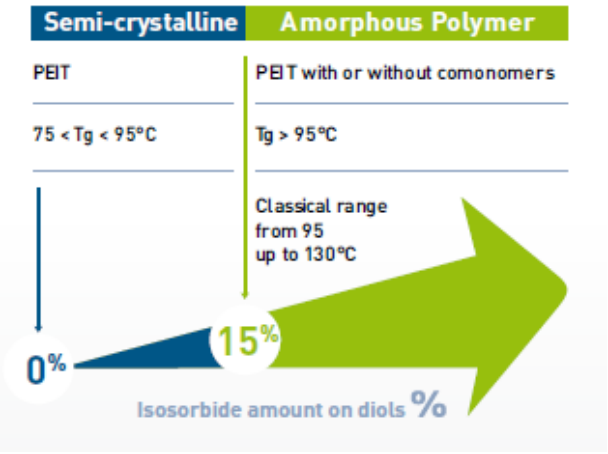
- Thermal properties, for example, increasing T_g the glass transition temperature
- Chemical resistance, to both water and organic solvents (such as acetones and esters)
- Optical performance, characteristics such as transparency and birefringence
- UV resistance, reduced yellowing upon exposure to the sun
- Mechanical properties, such as scratch, impact and bending resistance
- Adhesion, a crucial property for the CASE sector.
- Appearance, for instance imparting high gloss

Isosorbide can reduce the environmental burden associated with the use of existing materials, while maintaining performance, or enable the realisation of new performance profiles, to meet the exacting requirements of different markets.

Let's take a closer look at how isosorbide modifies the properties of PET and at the industrial value of the resulting materials.

Industrial applications for isosorbide: PET

PET is a copolyester of ethylene glycol and terephthalic acid, both of which are essentially petrochemical feedstocks. Replace some of the ethylene glycol with isosorbide and you have polyethylene co-isosorbide terephthalate (PEIT). A defining feature of this material is an elevated T_g, with T_g increasing relative to PET by over 1°C for every 1 mol% of diols switched to isosorbide. Depending on the extent of isosorbide replacement PEIT is either semi-crystalline or amorphous (see below); both types of polymer have compelling properties for innovative packaging, both recyclable and reusable.



Incorporating isosorbide addresses an important constraint of PET, efficiently increasing T_g.

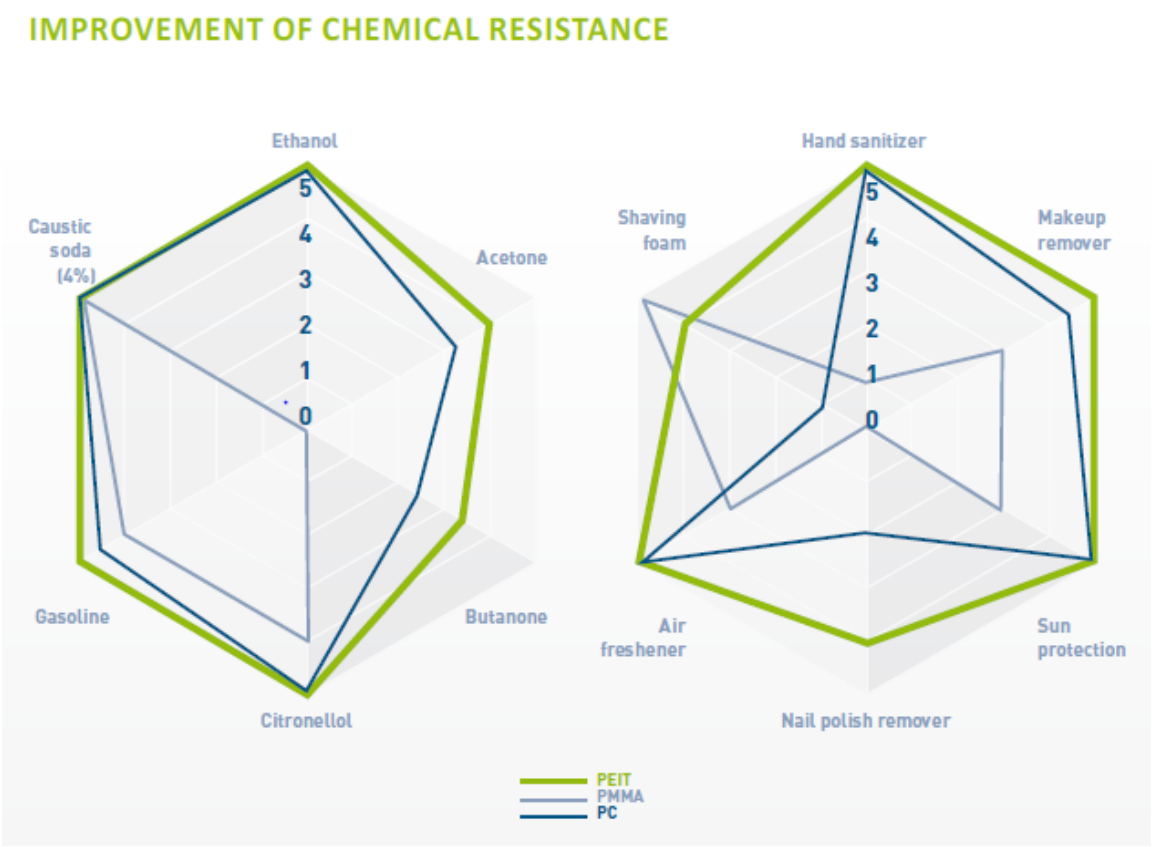
Semi-crystalline PEIT (PEITsc)

Semi-crystalline polymers have an ordered structure and sharp melting point. Prized for their ability to produce tough finished components with excellent strength and stiffness they can be difficult to thermoform.

The higher T_g of PEIT, relative to PET, is particularly advantageous for ***aerosol packaging***. Plastic aerosols are lightweight, chemically resistant, low cost and safer to store than metal alternatives. Unlike PET, PEITsc has the thermal resistance required to meet the criteria laid out in European Aerosols Federation (FEA) Standard 647.[2] It therefore answers directly to the trend away from metal towards plastic aerosol packaging.

The enhanced thermal properties of PEITsc are equally advantageous when it comes to ***beverage packaging***, for hot filling and pasteurization. With hot filling, vegetable and fruit juices, water, teas and other soft drinks, are heated and and filled at high temperature to ensure sterilization of the bottle and closure system; pasteurization is an alternative preservation technique for drinks such as beer. PEITsc eliminates any requirement for a vacuum panel, increasing design flexibility. PEITsc beer bottles have proven resistance to deformation during pasteurization at 60°C for 15 minutes.

Beyond thermal properties, PEITsc has excellent chemical resistance making it a strong contender for ***personal care and cosmetic packaging***, particularly for products containing polar molecules (e.g. nail polish remover, shaving cream and make-up remover). Incorporating isosorbide produces chemically inert, high gloss packaging with good optical properties and excellent impact resistance. This is a compelling packaging profile for high value products.



PMMA is polymethylmethacrylate

PEIT scores well on chemical resistance to a wide range of chemicals and personal care products.

All these performance benefits are accessible with no loss of recyclability relative to PET. PEITsc can be recycled directly into existing PET waste streams with recycled materials containing up to 50% modified PET fulfilling all the European PET Bottle Platform (EPBP) Testing Protocols for assessing PET recycling compatibility.[3] PEITsc can also carry the Resin Identification Code (RIC) #1.[4]

Amorphous PEIT (PEITam)

Amorphous polymers are dominated by randomly ordered molecular structure and tend to soften with the application of heat, rather than exhibiting a sharp melting point. This makes them easy to thermoform, to manufacture products with high dimensional stability and good impact resistance.

PEITam shares the chemical resistance of PEITsc making it similarly attractive for ***personal care and cosmetic packaging*** depending on the product and packaging design. It can be processed in just the same way as PET, using existing equipment.

When it comes to reusable plastic packaging, PEITam is more environmentally friendly than PET, but with no loss of performance. For example, PEITam reusuable ***sports bottles*** have excellent scratch and fingerprint resistance while reusable ***food containers*** are dishwasher proof and offer better staining resistance relative to PET. Safety and the assurance of a non-endocrine disruptor monomer are highly advantageous for these applications.

PEITam carries the RIC #7[4] and is recycled along with other polymers such as PC and other bioplastics.

Looking ahead

Isosorbide is a plant-based, sustainable monomer with a low carbon footprint and significant potential for a wide range of applications. Substituting isosorbide for existing petrochemical ingredients not only lightens the environmental impact of industrial polymers, it also drives up performance. New types of aerosol packaging, touch screens with enhanced clarity and scratch resistance, better adhesives with improved UV and impact resistance. These are just some of the products that isosorbide is already beginning to deliver as polymer chemists and formulators learn exactly what it can do.

**Internal comparative study based on life cycle analysis methodology, peer-reviewed by an external auditor.*

References

[1]http://plastics-themag.com/Plastic-packaging:-the-unloved-that-would-benefit-from-being-better-known

[2] FEA Standard 647: Plastic Aerosol Dispensers – Technical Requirements. Available to download at: https://www.aerosol.org/mediaroom/fea-647-and-fea-650-are-now-available/

[3]"How we do a Recycling Evaluation !" https://www.epbp.org/page/5/layout-link-2-test-procedures

[4]ASTM D7611/D7611M – 20 Standard Practice for Coding Plastic Manufactured Articles for Resin Identification. Details and available to purchase: https://www.astm.org/Standards/D7611.htm