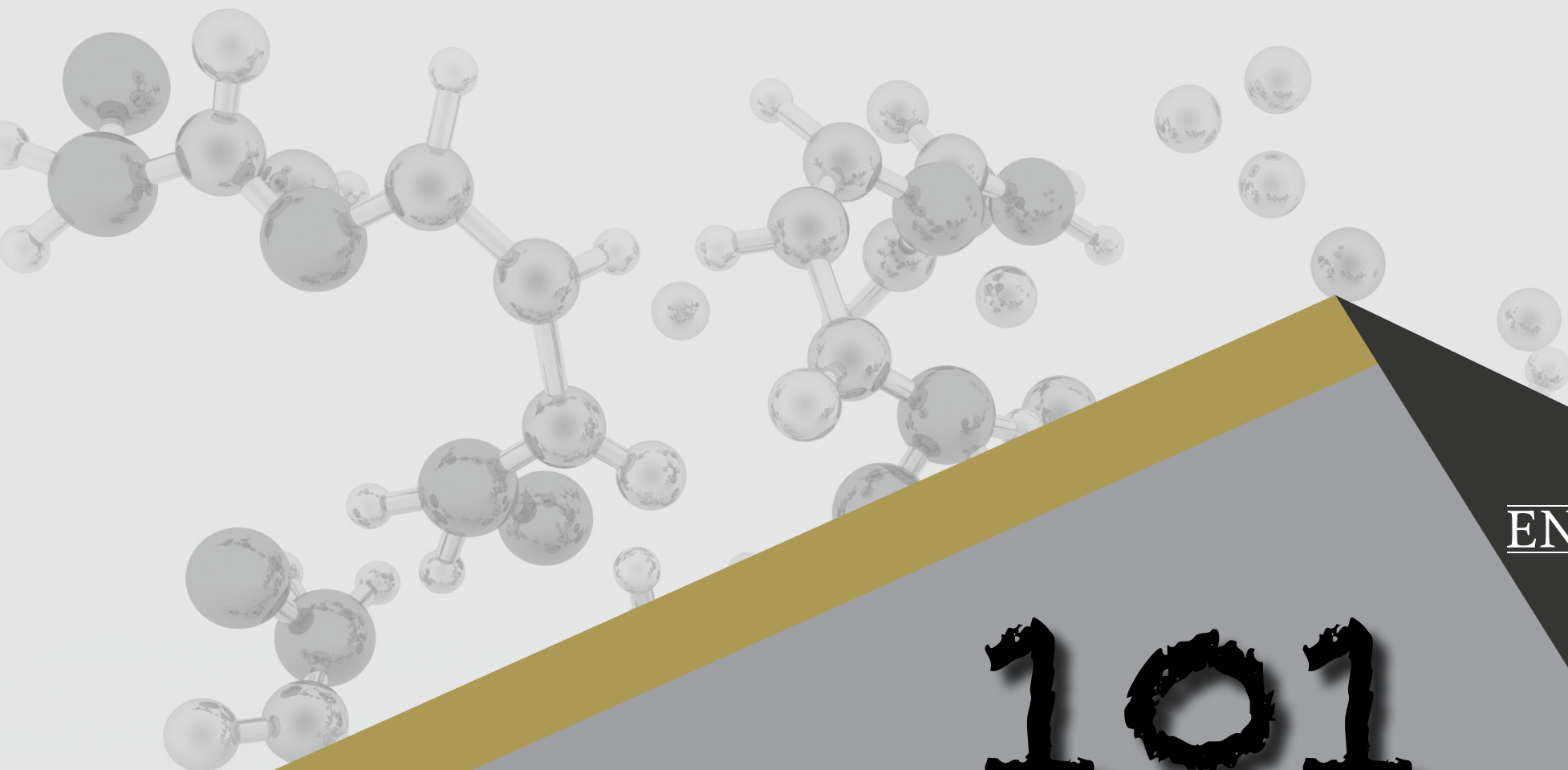


POLYETHYLENE



ENTEC

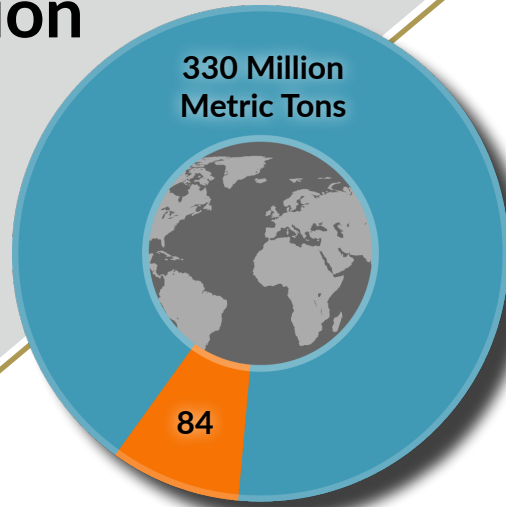
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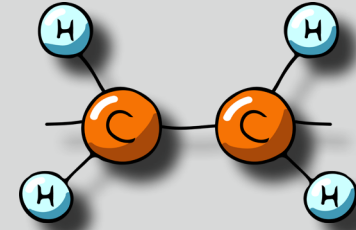
Polyethylene is the largest volume polymer produced globally with about

84 Million

Metric Tons produced.



Polyethylene is a simple molecule composed of hydrogen and carbon atoms but can be found in a diverse array of applications from film, food packaging, bags, containers, toys, automotive parts, fibers & fabrics, and pipe.



Polyethylene types can be broken down into several broad categories such as:

HDPE

LLDPE

LDPE

Polyolefin
Elastomers

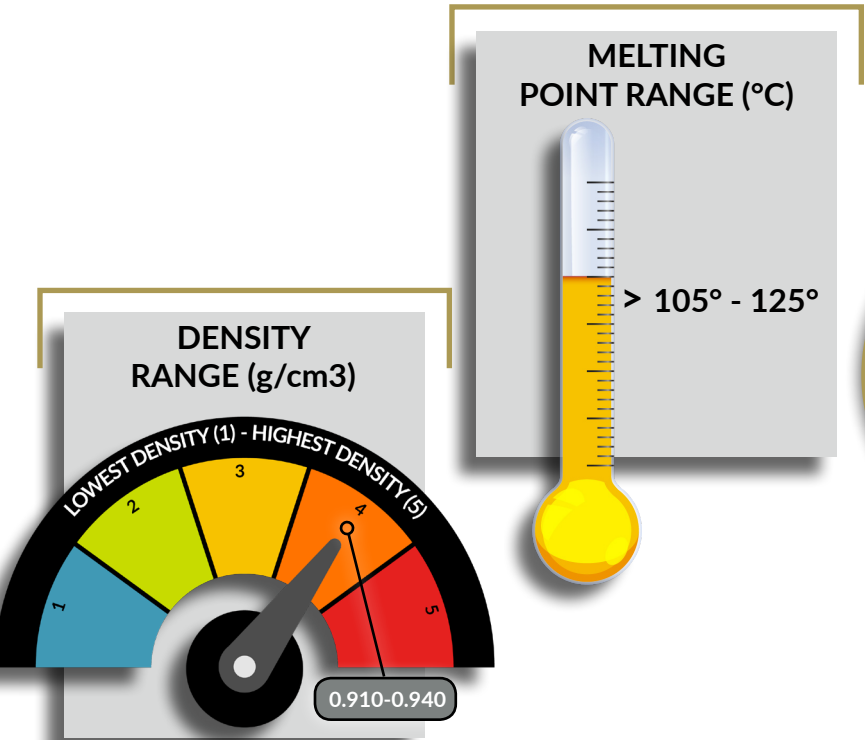
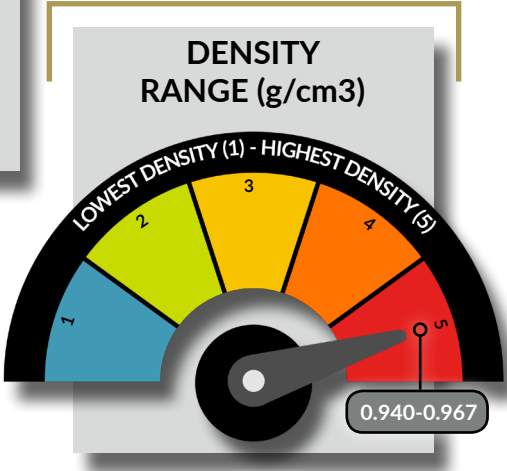
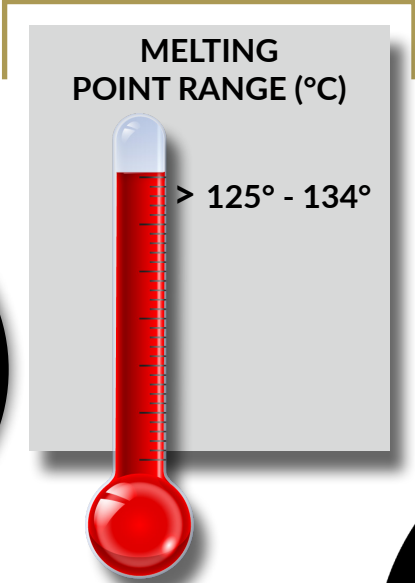
Olefin Block
Copolymers

Copolymers

Important properties in polyethylene include density (crystallinity), molecular weight (melt index) and molecular weight distribution. In addition, the type and amount of comonomer is also important in LLDPE and copolymers.

High Density Polyethylene (HDPE) is defined as having a density greater than 0.940 g/cm³. HDPE is the most widely used type of polyethylene and has the highest mechanical properties (tensile strength and stiffness) in the polyethylene family. Because pure linear HDPE can be brittle and is prone to environmental stress cracking, small amounts of alpha-olefin comonomers are added. These comonomers may be 1-butene, 1-hexene or 1-octene and will reduce the crystallinity (density) and improve environmental stress crack resistance. HDPE can be polymerized by several different methods which affect the molecular weight and molecular weight distribution, resulting in different properties and processability between HDPE products polymerized by different resin producers.

HDPE



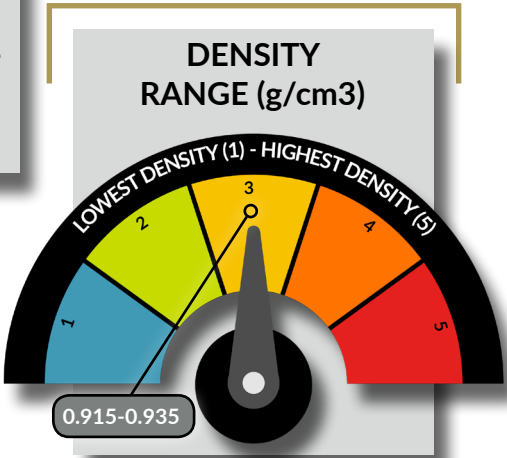
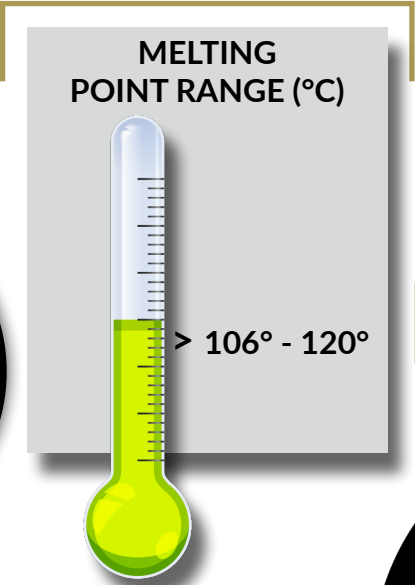
LLDPE

Linear Low Density Polyethylene (LLDPE) is defined as having a density between 0.910 and 0.940 g/cm³. It should be noted that LLDPE is sometimes broken down into two sub-categories: 0.910 to 0.930 g/cm³ is defined as LLDPE while a density range of 0.930 to 0.940 is defined as medium density polyethylene (MDPE). LLDPE is produced by incorporating higher amounts of alpha-olefin comonomers which reduce the density, improve optics and improve toughness and tear properties. Some LLDPE grades contain small amounts of long chain branching to help improve processability, especially in blown film applications.

Adding higher levels of comonomers results in very low density polyethylene (VLDPE) and ultra-low density polyethylene (ULDPE). These products are typically in the density range of 0.885 to 0.915 g/cm³. VLDPE and ULDPE offer improved toughness, puncture, tear resistance and environmental stress crack resistance compared to LDPE. These products are often used in film application requiring good puncture and tear resistance and improved cold temperature toughness. Other applications include flexible tubing, bag-in-box, low temperature packaging (ice bags) and medical packaging.

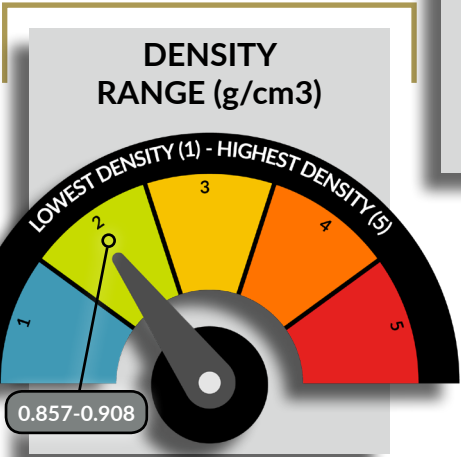
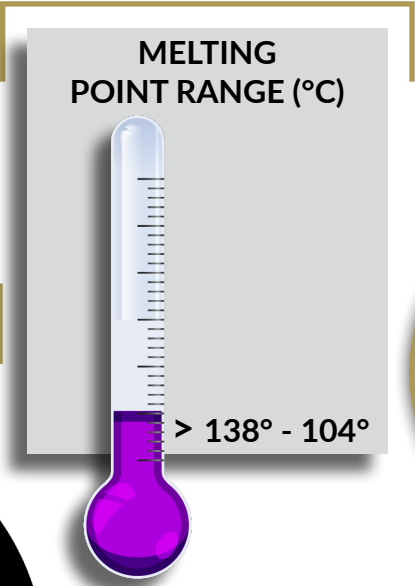
Low Density Polyethylene (LDPE) is defined as having a density of 0.915 to 0.935 g/cm³. LDPE is noted for having higher amounts of long-chain-branching which gives it high melt strength and shear-thinning for improved processability especially in blown film and extrusion coating applications. LDPE can be produced in autoclave or tubular reactors. LDPE is commonly used in blown film and extrusion coating applications as well as injection molding where good clarity is important.

LDPE

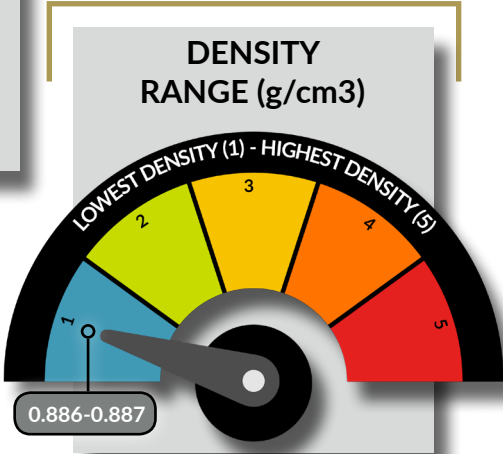
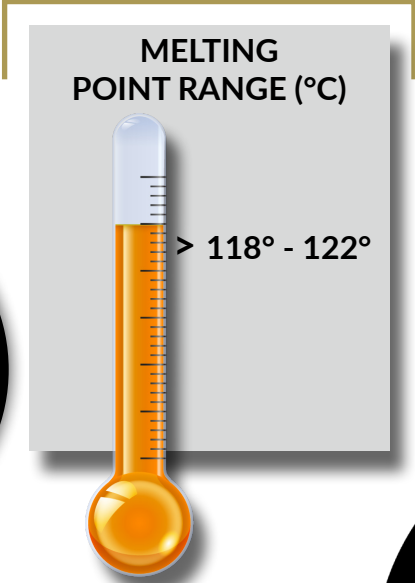


Polyolefin Plastomers and Polyolefin Elastomers: Polyolefin plastomers (POP) and polyolefin elastomers are produced using single-site or metallocene catalysts. POPs and POEs have a lower density range than traditional LLDPE material. POPs are defined as having a density from 0.885 – 0.910 g/cm³ and POEs have a density of 0.880 g/cm³ or lower. POPs/POEs have a narrow molecular weight distribution and a narrow short chain branching distribution which leads to lower melting points compared to more traditional LLDPE products. POPs and POEs can be produced using butene, hexane or octene comonomers. Typical applications include film packaging for sealant, puncture or abuse layers and as impact modifiers in PE and PP compounds. Higher density grades can be injection molded or extruded for use in applications requiring softness and high flexibility.

POP & POE



Olefin Block Copolymers: Olefin block copolymers (OBCs) are relatively new polymers that have a block structure consisting of segments of ethylene and alpha-olefin comonomers arranged into alternating blocks of hard and soft segments. The hard blocks contain little or no alpha-olefin and therefore have a higher crystallinity and higher melting point. The soft blocks contain higher levels of alpha-olefin and are softer, more flexible and have a lower melting point. One advantage of OBCs over POPs/POEs is that they maintain a higher melting point of approximately 120°C and have higher elastic recovery characteristics. OBCs can be used in film, extrusion and injection molding applications. Because of their higher and narrower recrystallization temperature compared to POPs / POEs, OBCs offer faster processing cycles.

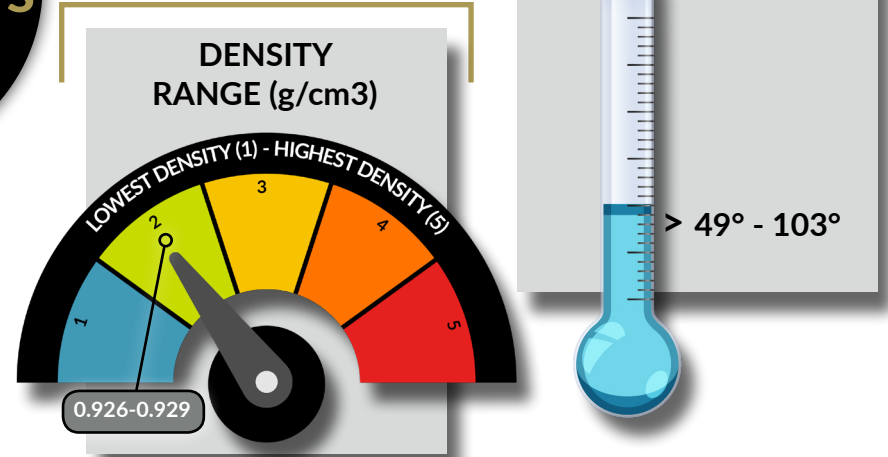
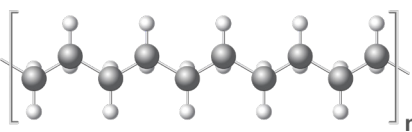


Summary Table of Polyethylene Types

POLYETHYLENE TYPE	DENSITY RANGE (g/cm3)	MELTING POINT RANGE (°C)
HDPE	0.940 - 0.967	125° - 134°
LLDPE	0.910 - 0.940	105° - 125°
LDPE	0.915 - 0.935	106° - 120°
POP / POE	0.857 - 0.908	38° - 104°
OBC	0.886 - 0.887	118° - 122°

Copolymers

Polyethylene Copolymers contain comonomers that can impart a range of special properties and characteristics to polyethylene depending on the type and amount of comonomer.



Ethylene Vinyl Acetate (EVA): Adding vinyl acetate produces an ethylene vinyl acetate (EVA) copolymer. EVA has more flexibility and a lower melting point than LDPE. In addition, the added polarity from the vinyl acetate allows EVA to adhere to more polar polymers such as PVC, PVDC, CPE, PS and PET. Increasing the levels of vinyl acetate reduce the crystallinity and melting point but improve the clarity. Higher levels of vinyl acetate also increase the density. High flow, high vinyl acetate grades of EVA are used for hot melt adhesives.

EVA

Acrylic Acid Copolymers: Copolymers of ethylene and acrylic acid (EAA) or methacrylic acid (EMAA) have a high level of long chain branching and therefore have good melt strength. Increasing the acid levels improves the adhesion to non-polar substrates such as aluminum foil, metallized substrates and paper. Higher acid content also improves resistance to oils and greases so acrylic acid copolymers are often used in flexible packaging applications such as laminated tubes, aluminum foil packaging, pouches and sachets, aseptic packaging, and meat and cheese packaging.

EAA & EMAA

Ethylene Acrylate (EMA, EEA, and EBA): Adding an acrylate comonomer (methyl, ethyl or butyl) to polyethylene also reduces the stiffness and melting point, similar to what occurs with EVA. The acrylate comonomer is also polar allowing it to have compatibility and adhesion to a wide range of polar polymers such as PC, polyester, PVC, cellulose, PVDC and glass and metal. Acrylate copolymers are often used as modifiers in polymer compounds, in extrusion coating applications, in wire & cable compounds and as carrier resins for colorants and additive masterbatch concentrates.

EMA, EEA & EBA

Ionomers: Ionomers are acrylic acid copolymers that have been partially neutralized with a zinc, sodium or lithium salt. Ionomers are only partially neutralized so they still have some acid functionality which provides for excellent adhesion to metal foil, nylon and paper. Ionomers are known for their high clarity, toughness, abrasion resistance and resistance to oils and greases. Ionomers are commonly used in extrusion coating and lamination, laminated glass, and applications requiring high impact/toughness such as golf ball and bowling pin covers. Zinc ionomers are also used as impact modifiers in nylon compounds.

Ionomers