

**THE CHEMISTRY
OF
POLYETHYLENE INSULATION**



EQUISTAR
A Lyondell Company

THE CHEMISTRY OF POLYETHYLENE INSULATION

Extruded dielectrics, cable jackets, and semi-conductive compounds are common expressions in the field of medium and high voltage cables; but what are they, what are they made of, why are some pliable and other tough and stiff? They are all polymers or copolymers or polyethylene. So what is the difference between them?

The two major subdivisions of the large and still growing family of plastics-thermosets and thermoplastics-are based on their behavior toward heat.

Thermosets, or thermosetting plastics, soften only once under heat and do not soften again on subsequent heating. Thermoplastics, on the other hand, can time and again be softened by heating and made rigid by cooling. Polyethylene is a member of a series of related chemical compounds called polyolefins and is a thermoplastic. This article is mainly concerned with polyethylene and its copolymers.

The physical properties of a polyethylene resin are mainly though not exclusively dependent on basic molecular properties such as short chain branching, average molecular weight and molecular weight distribution. These basic properties in turn are controlled by the size, structure and uniformity of the polyethylene molecules. Ethylene is a gaseous hydrocarbon composed of two carbon atoms and four hydrogen atoms, C_2H_4 , arranged as indicated in Fig. 1.

The two carbon atoms in the ethylene molecule are held together by a strong bond characteristic for some hydrocarbons. Under certain conditions, however, this bond will "open" as shown in Fig. 2. This enables an ethylene molecule to join with others to form a chain in which all the carbon atoms are linked. Such a chain of ethylene molecules is called polyethylene. Polyethylene chains are not flat or two-dimensional as Fig. 3 appears to indicate. They have a three-dimensional shape, the hydrogen atoms being arranged along an inner zigzag chain of carbon atoms. Polyethylene chains may be rather short or enormously long and consist of many thousands of atoms. In fact, the polymerization of ethylene creates a mixture of chains of unequal length; some of them may be very short, about 12 molecules or less, while others are giants containing several hundred thousand ethylene units.

There is no commercial polyethylene that is built up exclusively of chains as simple as the one presented in Fig. 3. The molecular structure of most commercial low density polyethylene resins is far more complicated. Laboratory examination has revealed that for every 100 ethylene units in the molecular chain there are roughly 1 - 10 branches (some of them other than ethylene) growing from the chain. The molecule therefore is not a straight chain but one with a great number of short and long side branches. Figure 4 shows a schematic picture of such a side branching chain; the branches radiate three-dimensionally, just as the branches of a tree point in all directions from various places along the trunk.

The presence of such side branches is a reason for variations in a number of important physical properties (such as density, hardness, flexibility and melt viscosity) which distinguish polyethylene resins. Chain branches also become points in the molecular network where oxidation may take place. Chain branching is not the only complication in the molecular structure; crosslinking (Fig. 5) is another. Such linking takes place between carbon atoms in neighboring chains. A network of crosslinked molecular chains may be compared to a number of heavily branched trees joined together somewhere along their branches - a highly intricate, three-dimensional molecular structure.

Intentionally crosslinked polyethylene or polyethylene copolymer resins are useful for wire and cable coating. Resins of this type may be compounded with a very high content of carbon black or other fillers. Controlled crosslinking results in a resin with outstanding physical and heat resistant properties without impairing other essential properties. However, by crosslinking the polyethylene molecules, the polymer is changed from a thermoplastic to a thermoset and thus cannot be softened and reused. Polyethylene can be crosslinked by adding a peroxide and subjecting the mixture to heat and pressure or by irradiating the end product with electrons or gamma rays. Both of these are free radical processes. An alternative method is to graft into the polymer chain a silane substituent which will undergo a number of reactions, resulting in a crosslink when exposed to moisture. These various crosslinking mechanisms are discussed later.

ORDER AND DISORDER IN POLYETHYLENE

Polyethylene molecules are not all arranged parallel to each other. In some areas of the plastic mass the molecular chains, though branched, are closely packed and lined up parallel in an orderly crystalline fashion. In other areas, the chains are randomly arranged like boiled spaghetti. This structure is what the chemist calls amorphous. Above its melting point, polyethylene is always an amorphous mass.

A polyethylene that remains totally amorphous at room temperature would be soft and greasy and thus useless for extrusion or molding applications. A totally crystalline polyethylene, on the other hand, would probably be too hard and brittle to be useful. The right mixture of crystalline and amorphous regions is what the processor needs to make good end products. Figure 6 shows schematically the distribution of crystalline and amorphous areas. Low and medium density polyethylenes made by the high-pressure process generally have crystallinities ranging from 40 to 60%. High density polyethylene resins consist of molecular chains with only a few occasional branches. Therefore, the chains can be packed more closely. The result is higher crystallinity, up to 80%.

An increase in crystallinity has a decided influence on some essential properties. The higher the degree of crystallinity, the denser the resin. Density, in turn, favorably influences a host of end product properties. One of these effects is easy to understand; since there is less space between the more closely packed molecular chains, articles made of more highly crystalline or more dense polyethylene are less permeable to gases and moisture. Gases and moisture penetrate more readily through the amorphous areas.

Perhaps equally as important as the amount of crystallinity are the size and size distribution of the crystalline regions. Although information in this area of polymer chemistry is still limited, it is known that changes in size and size distribution of crystalline regions in polyethylene will affect stress crack resistance, brittleness and other properties. Generally speaking, it has been found that for a given amount of crystallinity in a polyethylene, a uniform distribution of small crystalline areas will result in the most favorable properties for most applications.

BASIC MOLECULAR PROPERTIES AFFECT RESIN AND END PRODUCT PROPERTIES

Three basic molecular properties - short chain branching, average molecular weight, and molecular weight distribution - affect most of the mechanical and thermal properties essential for processing polyethylene and obtaining good end products. Small variations in the molecular structure may improve or impair some of these properties considerably. The electrical properties of a polyethylene resin, on the other hand, are only slightly affected by these three basic molecular factors. Polyethylene resins are currently available across a broad range of densities, about 0.88 g/cc to 0.96 g/cc. A classification dividing polyethylene resins into five ranges of density is generally used by the ASTM. These ranges are shown in Table 1. The earliest polyethylene resins, e.g. LDPE, also known as high pressure polyethylene or conventional polyethylene, had densities in the range 0.910 to 0.926 g/cc. Chronologically, these were followed by the high density polyethylenes (HDPE), also known as linear polyethylene or low pressure polyethylene, which exhibit densities between 0.940 and 0.965 g/cc. In the early 1980's, techniques for manufacturing linear low density polyethylene were introduced and, more recently, the very low density polyethylenes (i.e. those with a density less than 0.910 g/cc) were added to the family of polyethylene resins.

LOW DENSITY POLYETHYLENE

LDPE is made at high pressure (20,000 psi to 40,000 psi) and temperature (300°F to 575°F), in either autoclave or tubular reactors. The reaction is initiated with a peroxide which generates free radicals, causing the double bonds of the ethylene molecule to open and one molecule to add to another. However, under the extreme conditions used, the molecules do not add linearly, and the growing polymer chain undergoes complex reactions which lead to the formation of short side chains. It is these side chains which inhibit the polymer molecules from crystallizing perfectly, and lead to the observed density range given in Table 1. In addition, the free radicals may abstract a hydrogen atom from a polymer chain, and another polymer chain can grow from this site attached to the old polymer. This structure is known as long chain branching, and has a significant influence on the melt flow properties of the polymer. Employing the vast data base generated over the past 50 years, today's manufacturers of low density polyethylene are able to tailor these polymers to provide desired combinations of density and melt flow characteristics.

HIGH DENSITY POLYETHYLENE AND LINEAR LOW DENSITY POLYETHYLENE

HDPE is synthesized under much less extreme conditions than LDPE. The pressure is typically in the 600 psi range and temperatures vary from 185°F to 225°F. Catalysts are based on transition metal elements and are highly active. The reactors are operated either in the gas phase or as slurry reactors using, for example, isobutane as the working fluid. Under these conditions, ethylene polymerizes, attaching one molecule to another to form long linear chains of differing lengths. The choice of catalyst and operating conditions controls the variety of chain lengths; the greater the variety, the broader the distribution and the easier the processing. If butene-1 or hexene-1 is introduced together with the ethylene, these molecules will become incorporated into the growing polymer chain as shown in Fig. 7.

The ethyl (C₂) and butyl (C₄) side chains interfere with the chain folding crystallization process and, as the number of side chains increases, the material exhibits a lower density. Because of its size, the butyl side chain disrupts the crystallization process more effectively than the ethyl side chain. Partly as a result of the effect on the crystallization process, hexene copolymers exhibit better stress crack/stiffness properties than the corresponding butene copolymers. This stress crack/stiffness relationship is very noticeable in thin-walled containers, for example milk bottles, and is also observed to a lesser extent in wire and cable insulations and jackets. Sometimes a mixture of hexene and butene is fed to the reactor to further modify the properties.

LLDPE, i.e. linear low density polyethylene as the name implies, covers the same density range as LDPE. However, since this material is not made with the free radical catalyst but with a heterogeneous catalyst like HDPE, the polymer chains do not exhibit any long chain branching - only the short chain branching introduced through the use of butene, hexene or octene comonomer.

MEDIUM DENSITY POLYETHYLENE

Several methods exist for manufacturing medium density polyethylene. It may be manufactured directly using either the high pressure process or the low pressure process. In the latter, the amount of butene and/or hexene fed to the reactor generates more side chains and the density is thus lowered. Alternatively, two polymers, one high density and one low density, can be melt blended to achieve the density required.

VERY LOW DENSITY POLYETHYLENE

Very low density polyethylenes, as the name implies, exhibit densities less than 0.910 g/cc. These materials are manufactured at moderate pressures using heterogeneous catalysts and comonomers of propylene, butene, hexene or octene. These products are still in their infancy with regard to wire and cable applications but certainly show interesting electrical insulation properties.

COPOLYMERS

Modifying the molecular structure of a polyethylene by the addition of one or more dissimilar monomers to the polymer results in copolymers. The most frequently used comonomer in high pressure ethylene copolymerization is vinyl acetate, although acrylates such as n-butyl acrylate are being more frequently used. The structure of these two copolymers is shown in Fig. 8. Ethylene-vinyl acetate copolymers (EVA), varying in vinyl acetate incorporation from 1 wt.% to 60 wt.% are commercially available. However, those most commonly used in the wire and cable area have approximately 18 to 28 wt.% of vinyl acetate incorporation.

Linear low density polyethylene (LLDPE) and some high density polyethylenes (HDPE) are ethylene copolymers produced employing a variety of olefin comonomers, e.g. butene, hexene and octene, leading to the structures shown in Fig. 7. Polar molecules, such as vinyl acetate, cannot be used with heterogeneous catalysis since they inhibit the polymerization reaction.

EFFECT OF CHANGES IN AVERAGE MOLECULAR WEIGHT

Every polyethylene consists of a mixture of large and small chains consisting of molecules of high and low molecular weights. The average of these molecular weights is the second basic molecular property. The polymer chemist distinguishes between several average molecular weights arrived at by various methods, too involved to discuss in this article. Within limitations, these average molecular weights are inversely related to the melt index. In other words, as average molecular weight increases melt index decreases, and vice versa. Generally, polyethylenes most suitable for wire and cable applications should have a melt index in the range of 0.2 g/10 min. to 3.0 g/10 min.

MOLECULAR WEIGHT DISTRIBUTION

The molecular weight distribution, the third basic property of polyethylene, gives a general picture of the ratio of the large, medium, and small molecular chains in the resin. The molecular weight distribution is called narrow if the resin is made up of chains close to the average length; it is called broad if the resin is made up of chains of a wide variety of lengths. Figure 9 shows this in graphical form.

Actual molecular weight distribution curves often vary considerably from the shape of those shown in Fig. 9. Recent work in Equistar's laboratories has shown that the shape of the curves may be just as important as the overall distribution. For this reason, it is difficult to make simple correlations between molecular weight distribution and resin physical properties. Work is continuing in this area of polymer science research.

HOW DENSITY AND MOLECULAR WEIGHT AFFECT ESSENTIAL RESIN PROPERTIES

Table II shows how density and molecular weight affect essential properties of polyethylene. There are some properties that are definitely not influenced by either of these basic molecular factors, but depend upon other peculiar traits of the molecular structure, such as molecular weight distribution or configuration. There are possibly others for which such influence may be proved at some later date.

Table II shows that the two basic molecular properties may have contrary effects on certain resin or end product properties. In such cases, the end use will determine which properties are most essential and which polyethylene resin is best suited for a particular end use.

Melt index, although customarily used for classifying polyethylene resins, is not always a reliable guide with regard to processability and specific resin and end product properties. Sometimes there is little relationship between melt index and the suitability of a polyethylene for a specific application. Melt index must be used in conjunction with other yardsticks to describe the flow and mechanical properties of a resin.

VINYL ACETATE MODIFIED POLYETHYLENE

Vinyl acetate modified polyethylene resins are also used in the wire and cable industry. The incorporation of small amounts of vinyl acetate into polyethylene results in a resin which extrudes much like polyethylene, while providing the ability to accept filler loadings, e.g. carbon black. Actually a wide range of properties is possible, depending on the vinyl acetate content and the synthesis conditions used to produce the modified resin. Perhaps the most significant difference between unmodified polyethylene and vinyl acetate modified polyethylene is the role that resin density plays. While the density of polyethylene is a measure of crystallinity, the density of vinyl acetate modified polyethylene is a function of percent vinyl acetate. As vinyl acetate content increases, density increases and crystallinity decreases; thus, higher density results in lower stiffness, greater toughness, lower melting point and somewhat higher permeability. We find the opposite effects in unmodified polyethylene. The presence of the polar acetate group in the polymer also affects the dielectric constant and dissipation factor, both of which increase linearly with increase of vinyl acetate content.

WIRE AND CABLE COATING

Its unusual electrical properties make tough, flexible, chemically inert polyethylene an outstanding insulator for electrical wire and cable. High density polyethylenes are preferable to low density resins for some wire and cable coating applications. They have higher abrasion resistance and can better withstand mechanical abuse. High density resins also exhibit greater tear resistance than low density types, as well as higher tensile and shear strength.

High dielectric strength and very low electric conductivity make polyethylene an outstanding insulator for electric power cable at low as well as high transmission voltages. Polyethylene is also the most suitable dielectric for all types of high frequency cables because of its low dielectric loss at high frequencies and its remarkable mechanical properties.

The power factor of polyethylene which provides the measure of the power loss in the insulated conductor increases slightly with an increase in the temperature of the atmosphere or the electrical equipment, both of which may fluctuate widely. It also increases slightly with an increase in the humidity of the surroundings.

ANTIOXIDANTS AND CARBON BLACK FILLERS

The power factor of polyethylene may be unfavorably affected by oxidation of the insulator when exposed to excessive heat or light. Therefore, polyethylene compounds used for coating wire and cable that will be exposed to the degrading effects of heat must contain anti-oxidants. Cables exposed to ultraviolet rays in sunlight must also contain carbon black or other UV inhibitors; otherwise UV exposure would accelerate oxidation and degradation of the insulating or protective coating. Such additives also assure that the electrical and mechanical properties of the resin are preserved under the high temperatures prevailing in the extruder.

CROSSLINKED WIRE INSULATION

In the middle to late 1950s, crosslinkable polyethylene compounds were introduced for coating power cable and other specialized constructions. The unusual and outstanding electrical properties of polyethylene are extended to higher operating temperatures when used in crosslinkable materials. Crosslinked compounds, however, are not thermoplastic and will not melt upon reheating. The process of crosslinking changes polyethylene and EVA copolymers from a thermoplastic series of polymer chains into a single interwoven molecule, Fig. 10. This change produces improved heat resistance, allows compounds to incorporate higher filler loadings, improves environmental stress crack resistance and gives higher tensile strength.

Improved heat resistance is the most important advantage of crosslinked polyethylene (XLPE) over thermoplastic polyethylene. A power cable with XLPE insulation can operate at conductor temperatures of 90°C, while the thermoplastic polyethylene insulated cable operates at 75°C. Since conductor temperature is proportional to the amount of current sent through the cable, more power can be sent through an XLPE cable than through a non-crosslinked cable of the same size. Thus in heavily populated areas, fewer or smaller XLPE cables can be installed. In appliance wire applications, crosslinking allows compounds to be formulated for 125°C service temperatures, well above the melting point of the non-crosslinked base resin.

The second most important improvement in crosslinked polyethylenes and EVA copolymers is their capability to employ higher filler loadings without significant loss of physical properties. High filler loadings reduce the physical properties of the polymer, particularly the tensile strength and elongation. Crosslinking forms bonds around a filler, incorporating it into the polymer matrix and reducing its effect on the compound. By using a crosslinkable resin base, flame retardant, mineral filler or carbon black can be used in higher concentrations while maintaining physical properties at acceptable levels. This enables the development of highly flame retardant, abrasion resistant or semiconductive wire compounds while using relatively low cost polyethylene or ethylene-vinyl acetate base resins. One of the most successful commercial flame retardant wire and cable insulation compounds is based on a crosslinked EVA copolymer and contains greater than 50% by weight of a flame retardant filler. Millions of pounds per year of this patented product (U.S. Patent 3832326) have been used by the automotive industry since 1974.

PEROXIDE CROSSLINKED POLYETHYLENE

Peroxide systems are the most common method for crosslinking polyethylene. The equipment and compounding techniques are similar to those used for rubber vulcanization and have been in use for many years. Peroxide-containing resins and compounds can be extruded using conventional extruders, but at temperatures below that of the peroxide decomposition point. Most of the commonly used peroxides require processing in a range from 240°F to 260°F. Following extrusion onto the conductor, the compound is exposed in a continuous vulcanizer to high pressure steam (about 250 psi) which yields a temperature of about 400°F. Alternatively, dry nitrogen may be used to process the crosslinkable insulation at a pressure of about 150 psi when used in conjunction with a vulcanizer wall temperature of approximately 650°F. These high temperatures cause the peroxide to decompose into reactive free radicals, Fig. 11. The pressure is required to prevent void formation.

The peroxide-generated radicals react with the polyethylene or EVA polymers by extracting a hydrogen atom from the polymer. This reaction forms a radical on the polymer chain that reacts with another polymer chain radical to form a crosslink.

Compared to EVA copolymers, low density polyethylenes are relatively more difficult to crosslink using peroxides. LDPE is a non-polar molecule with all its hydrogen atoms tightly bound to carbon atoms. The lack of highly reactive hydrogens means fewer sites for radical attack and lower reaction rates. For this reason, low density polyethylene is principally used as a base resin for those applications requiring its superior dielectric properties, such as high voltage power cable insulation. Ethylene-vinyl acetate copolymers are more readily crosslinked and accept high filler loadings, making them well suited for lower voltage applications such as automotive, building and appliance wire, as well as medium voltage semi-conductive insulation or conductor shields. Linear low density and high density polyethylenes have not generally been used as base resin for peroxide crosslinkable polyethylene wire and cable compounds, since they are difficult to process in the low temperature ranges required for safe extrusion of peroxide-containing materials.

Radiation crosslinking has been performed since mid-1950. This original method used gamma radiation generated from a Cobalt-60 source. Unfortunately, while Cobalt-60 gamma radiation will penetrate a very thick polymer layer, the dose rates available (1 Mrad/hr) often require several hours of exposure. Units now utilize high power electron beam radiation, which provides high dose rates (100 Mrad/min) and gives more rapid crosslinking; only seconds of exposure are usually required for electron beam crosslinking. The chemistry of radiation crosslinking is similar to peroxide methods, except that high energy electrons rather than peroxides are used to extract hydrogen atoms from the carbon chain and generate the free radicals. After hydrogen abstraction, the polymer radicals combine in the same manner to produce the crosslinked material. However, radiation is performed at ambient temperatures and the most useful crosslinks occur in the amorphous regions of the polymer. Consequently, some subtle differences may be detected between radiation and peroxide crosslinked materials, where the latter are totally amorphous during the crosslinking step.

Radiation crosslinking is performed by passing the wire or cable through a beam of electron radiation. Usually, the full dose (10-20 Mrad) is not applied in a single pass because of the rapid temperature increase (about 5°C per megarad) that accompanies electron beam exposure. To solve this problem, the wire or cable is usually festooned on a series of pulleys and passed through the beam several times until the desired total dose is reached.

Radiation processing is most commonly used in the production of appliance wire and control cable. These applications are most suitable because of their relatively thin insulating layers, which allow penetration of low power electron beams. The materials used for this procedure are similar to those used in peroxide curing, except that the peroxide has been eliminated, and, in some cases, a crosslinking accelerator has been added or the base resin tailored to provide optimum properties. The quality and physical properties of radiation crosslinked material are virtually identical to those produced by peroxide curing.

WATER CURABLE COMPOUNDS

Moisture curable polyethylenes provide a third process for manufacturing, crosslinkable materials. In this case, a vinyl silane is either copolymerized (high pressure process only) or grafted to the polymer backbone, Fig. 12. During extrusion of the thermoplastic silane containing compound onto the conductor, a catalyst is added, then the cable is stored in an elevated temperature (about 70°C), high humidity cabinet (80% RH), or water bath (about 80°C). Under these conditions, the reactions shown in Fig. 12 occur, resulting in the formation of a crosslinking bridge between two polymer chains. It may take several hours for the crosslinking reaction to achieve completion, depending upon conditions, and it occurs below the melting point of the resin. Since moisture has to diffuse into the material in order to crosslink the product, the time to completion of crosslinking is dependent upon the wall thickness of the cable. As might be expected, the process is most suitable for appliance wiring type cables, although it has been reported in Europe that thick-walled medium voltage cables have been successfully crosslinked in this manner.

Research work is in progress to determine the effect of the three differing crosslinking mechanisms - peroxide, radiation, and water cure - on the end use properties of polyolefins.

FIGURE AND TABLES

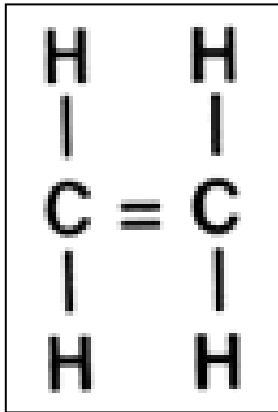


Fig. 1. Structure of Ethylene

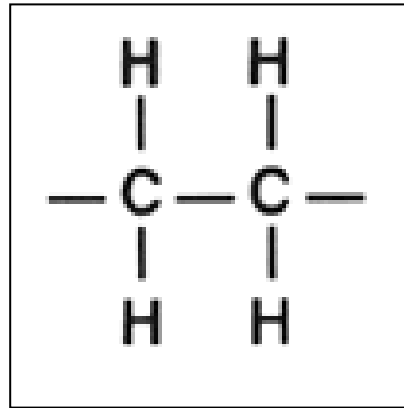


Fig. 2. The bond between the two carbon atoms has opened.

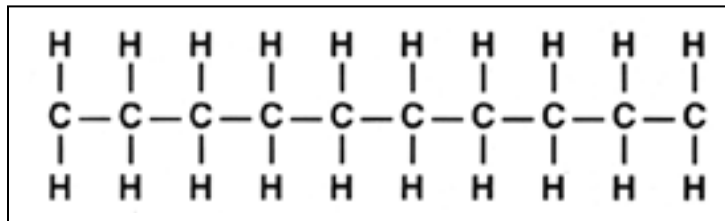


Fig. 3. Part of a Polyethylene Chain (or Molecule)

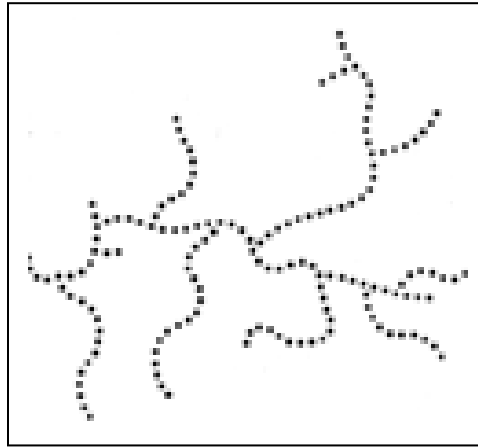


Fig. 4. Polyethylene Chain with Side Branches

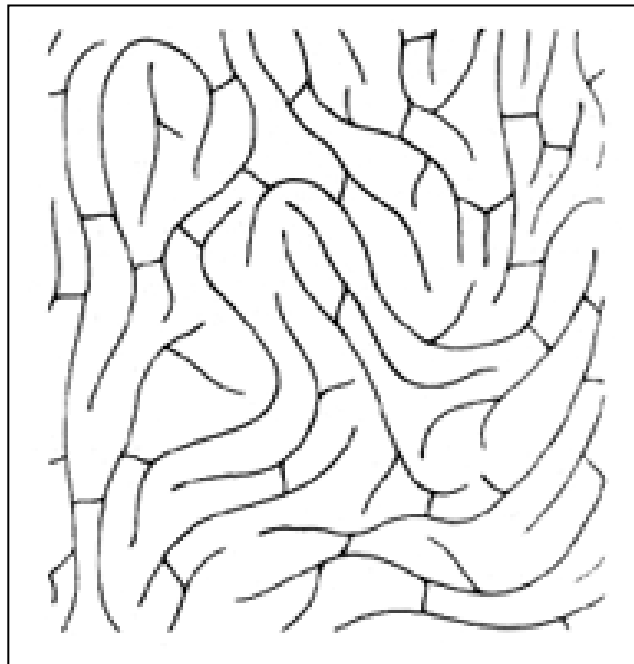


Fig. 5. Simplified Presentation of Crosslinked Polyethylene Molecules

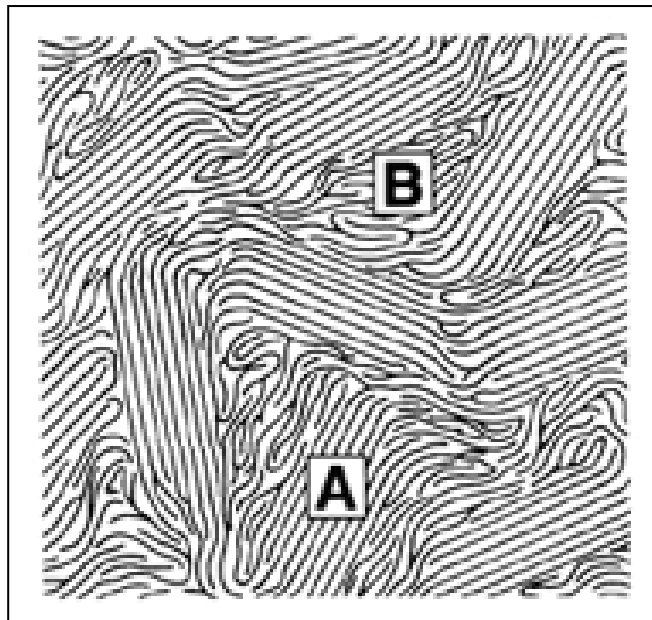


Fig. 6. Crystalline (A) and Amorphous (B) Regions in Polyethylene

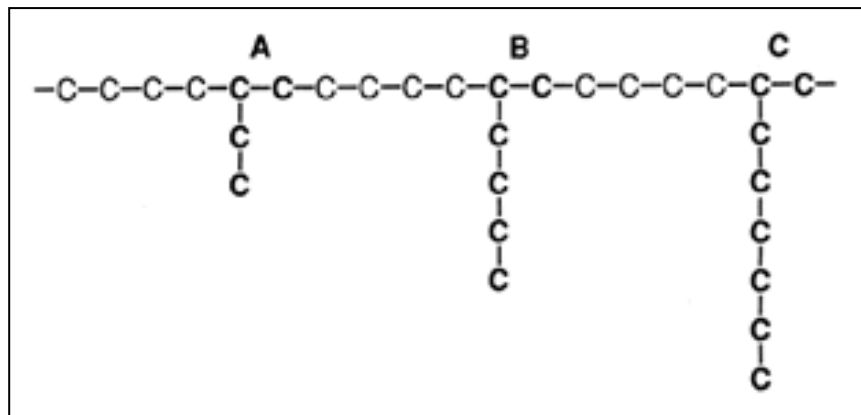


Fig. 7. Part of a linear polymer chain, showing the side branch structure when Butane (A) or Hexene (B) or Octene (C) is incorporated

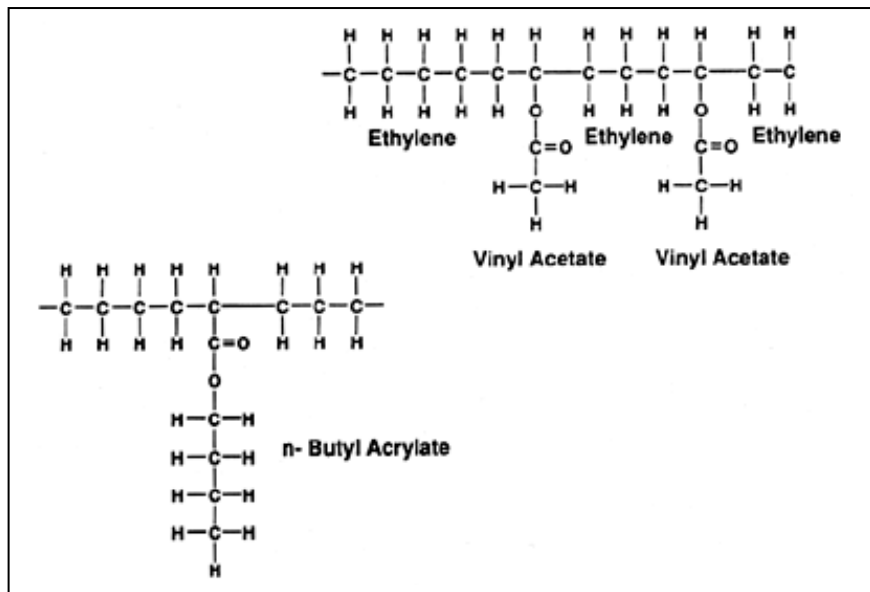


Fig. 8. Part of an ethylene-vinyl acetate and ethylene-n-butyl acrylate copolymer chain.

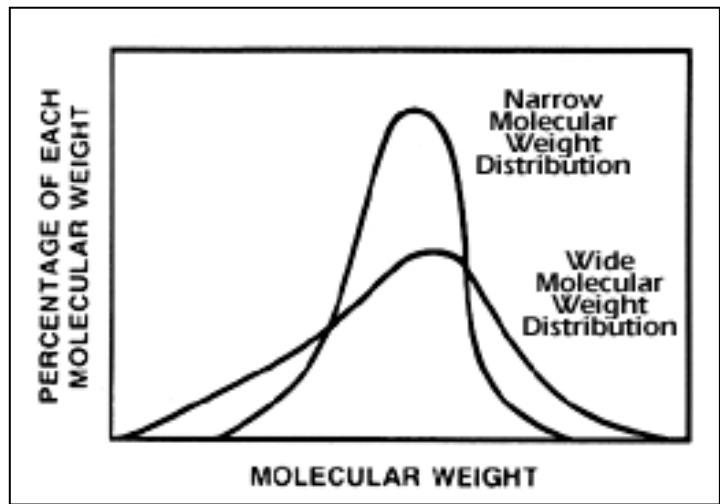


Fig. 9. Schematic Representation of Molecular Weight Distribution

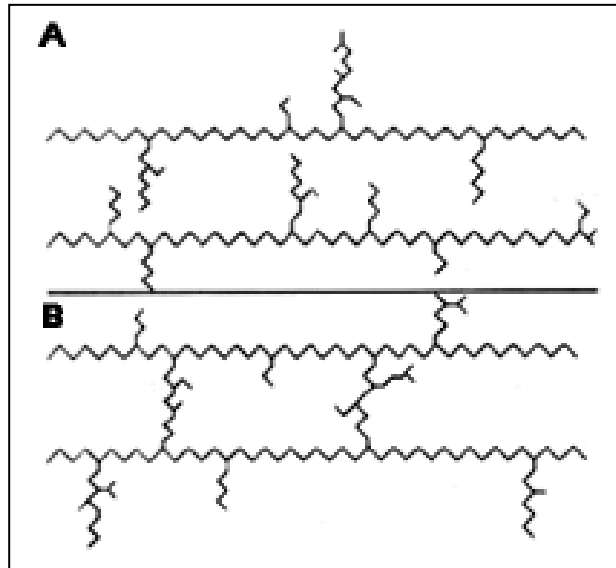


Fig. 10. (A) Non-Crosslinked LDPE. (B) Crosslinked LDPE

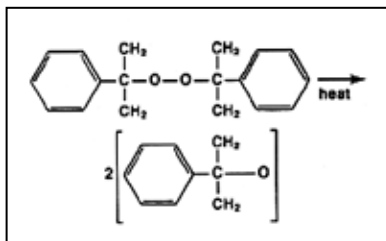


Fig. 11. Decomposition of Dicumyl Peroxide (a Common Crosslinking Peroxide)

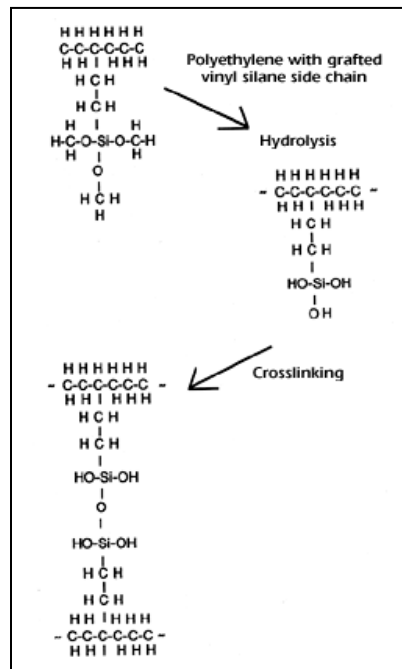


Fig. 12. Simplified Water Cure Reaction Mechanism

Table I. The 5 Density Ranges of Polyethylene

Density	g/cm ³	ASTM D 1248
Very Low	< 0.910	—
Low	0.910 – 0.925	Type I
Medium	0.926 – 0.940	Type II
High (Linear)	0.941 – 0.959	Type III
Very High	0.959 & >	Type IV

Table II. Effect of Changes in Density and Melt Index on Polyethylene Properties

Physical Properties	Molecular Properties	
	If Density Increases (Note 1)	If Melt Index Increases (Note 2)
Melt Viscosity		Lower
Vicat Softening Temperature		Lower
Surface Hardness (Abrasion Resistance)		Slightly Lower
Tensile Strength:		
Yield	Much Higher	Slightly Lower
Break	Slightly Lower	Lower
Elongation	Lower	
Resistance to Creep	Higher	Slightly Lower
Flexural Stiffness	Much Higher	Slightly Lower
Flexibility	Lower	—
Resistance to Brittleness at Low Temperatures	Lower	
Resistance to Environmental Stress Cracking	Lower	
Barrier Properties:		
MVT Rate	Lower	—
Gas and Liquid Transmission	Much Lower	—
Grease Resistance	Much Higher	Slightly Lower
Substrate Adhesion (Note 3)	Slightly Lower	Slightly Higher
Shrinkage	Higher	Lower
Warping	Slightly Higher	Lower
Electrical Properties	Slightly Higher	No Effect
NOTES:		
1. For density (or crystallinity) increase within the range of 0.915 to 0.965.		
2. For melt index increase or decrease in average molecular weight		
3. Especially, physical adherence to porous substrates.		



Lyondell Chemical Company
1221 McKinney Street, Suite 1600
P.O. Box 2483
Houston, TX 77252-2583

Cincinnati Technology Center
11530 Northlake Drive
Cincinnati, OH 45249
(513) 530-4000

The information in this document is, to our knowledge, true and accurate. However, since the particular uses and the actual conditions of use of our products are beyond our control, establishing satisfactory performance of our products for the intended application is the customer's sole responsibility. All uses of Equistar products and anywritten or oral information, suggestions or technical advice from Equistar are without warranty, express or implied, and are not an inducement to use any process or product in conflict with any patent.

Equistar materials are not designed or manufactured for use in implantation in the human body or in contact with internal body fluids or tissues. Equistar makes no representation, promise, express warranty or implied warranty concerning the suitability of these materials for use in implantation in the human body or in contact with internal body tissues or fluids.

More detailed safety and disposal information on our products is contained in the Material Safety Data Sheet (MSDS). All users of our products are urged to retain and use the MSDS. An MSDS is automatically distributed upon purchase/order execution. You may request an advance or replacement copy by calling our MSDS Hotline at (800) 700-0946).

© Alathon, Aquathene, Flexathene, Integrate, Microthene, Petrothene, Petrothene Select, Plexar and Ultrathene are trademarks of Equistar Chemicals, LP.