Polyethylene (PE) is a thermoplastic that contains chains of the monomer, ethylene. PE is most notably used for plastic shopping bags; it can also be used in plastic milk cartons and water bottles. There are three main types of PE; High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE) and Linear Low Density Polyethylene (LLDPE). The major differences in the shapes of the PE molecules arise from the changes that exist during the polymerization reaction. [1]

PE is composed of two elements, hydrogen and carbon. Because these elements have a very similar electronegativity (Carbon is 2.5 and Hydrogen is 2.1), the overall molecule does not tend to give up or accept electrons. [4] This results in PE being an excellent insulator.

PE is also resistant to many solvents, which can pose a problem when wanting to mark or decorate the plastic. In order for inks or paints to adhere to PE, the area needs to first come in contact with a flame or an electrical spark (Corona) in order to change the chemical structure of PE.

Different temperatures, pressures and catalysts during the polymerization reaction can have drastic effects on the branching of PE molecules. Branching is the formation of side chains off the basic polymer backbone. These side chains are formed when the hydrogen-carbon bond is broken during the polymerization reaction. [1] With a significant amount of branching on a PE molecule, the structure will become more amorphous and have longer, uninformed chains. The different structures have names associated with their respective densities (i.e. degree of branching); HDPE, LDPE, LLDPE.

High Density Polyethylene
HDPE is the most rigid among the three common PE's and has a density ranging from .935-.960 g/cm^3. [1] HDPE is the product of limited branching that occurs when the polymerization is at low temperatures and low pressure. Because of this limited breaching, HDPE is more crystalline; leading to the increased density. HDPE can be processed three different ways: slurry particle reactor, gas phase and metallocene catalyst. [2] HDPE is the plastic that is used in making fuel tanks because of its low permeability and superb chemical resistance.

Low Density Polyethylene
LDPE has great flexibility, impact toughness and stress cracking resistance. LDPE will have a density ranging from .910-.925 g/cm^3. [1] LPDE is polymerized under conditions of high temperature and high pressure. Because LDPE is processed under extreme conditions, the molecular structure is mostly amorphous. Because of the amorphous structure, the branches are very high in quantity and length.

Linear Low Density Polyethylene
LLDPE is essentially a mix of HDPE and LDPE. It is created by a low pressure polymerization process much like HDPE, but has more branches much like LDPE has. These branches are long enough to prevent the molecules from being closely packed together. This results in a linear molecule structure like HDPE, but also a low density like

LDPE. The density of LLDPE will typically range from .918-.940 g/cm^3. The LLDPE features can be achieved by adding a comonomer during the polymerization process; usually hexane, butane or octane. The comonomer increases chain entanglement, which results in improved physical properties as well as stronger secondary bonding. The downsides to LLDPE are higher melt processing temperatures, 8% greater shrinkage, less clear (optically) and less flexibility. [1]

Determining the right type of PE for an application can sometimes be difficult. Bleach and detergent bottles are usually made of HDPE because they need to be made with thin walls to reduce material costs, but they also need to be strong so they can hold their shape. Tupperware is also made of HDPE as well as milk jugs and folding tables. Shopping bags are often made with LDPE because it's lightweight and flexible and somewhat transparent as well as six-pack soda can rings and playground slides. LLDPE is used when LDPE and HDPE cannot be used, or when cost becomes an issue, including plastic wrap and stretch wrap.

[1] Strong, A. Brent, Plastics: Materials and Processing, Prentice Hall, 2000.

[2] Campo, E. Alfredo, The Complete Part Design Handbook, Hanser, 2006.

[3] Peacock, Andrew J.. Handbook of Polyethylene: Structures, Properties, and Applications. CRC Press, 2000.

[4] Callister, William D. Jr., Materials Science and Engineering, John Wiley & Sons, 2003.