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A Comprehensive Review on Effect of SIO2 in the Reinforcement of High-Density Polyethylene (HDPE)

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Abstract: Nano composites, a high performance material exhibit unusual property combinations and unique design possibilities. With an estimated annual growth rate of about 25% and fastest demand to be in engineering plastics and elastomers, their potential is so striking that they are useful in several areas ranging from packaging to biomedical applications. In this unified overview the three types of matrix Nano composites are presented underlining the need for these materials, their processing methods and some recent results on structure, properties and potential applications, perspectives including need for such materials in future space mission and other interesting applications together with market and safety aspects. Possible uses of natural materials such as clay based minerals; chrysotile and lignocellulose fibers are highlighted.
Keywords: Composite, Nano SiO_2, HDPE,

I. INTRODUCTION

High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a thermoplastic polymer produced from the monomer ethylene. It is sometimes called "alkathene" or "polythene" when used for HDPE pipes. With a high strength-to-density ratio, HDPE is used in the production of plastic bottles, corrosion-resistant piping. HDPE is known for its large strength-to-density ratio. The density of HDPE can range from 930 to 970 kg/m3. Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher. High-density polyethylene, unlike polypropylene, cannot withstand normally required autoclaving conditions. The lack of branching is ensured by an appropriate choice of catalyst (e.g., Ziegler–Natta catalysts) and reaction conditions. The physical properties of HDPE can vary depending on the molding process that is used to manufacture a specific sample; to some degree a determining factor are the international standardized testing methods employed to identify these properties for a specific process.

II. HDPE ADVANTAGES

A. Safety of potable water and long-term reliability
B. Resistance to corrosion, tuberculation, deposits
C. Flexibility to speed installations
D. Freeze-break res istance
E. Lightweight, easy to transport
F. Low scrap value, avoiding jobsite theft
G. Durability and toughness to survive jobsite installations
H. No flame used for joining, with many fitting and joining options
I. Recyclable, eco-friendly material
J. Heat fusible for virtually leak-free performance

III. SILICON DIOXIDE

Silicon dioxide, also known as silica, is an oxide of silicon with the chemical formula SiO_2, most commonly found in nature as quartz and in various living organisms. In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and most abundant families of materials, existing as a compound of several minerals and as synthetic product. Notable examples include fused quartz, fumed silica, silica gel, and aerogels. It is used in structural materials, microelectronics (as an electrical insulator), and as components in the food and pharmaceutical industries.

1) *Structural Use:* an estimated 95% of silicon dioxide (sand) produced is consumed in the construction industry, e.g. for the production of concrete (Portland cement concrete). Silica, in the form of sand is used as the main ingredient in sand casting for the manufacture of metallic components in engineering and other applications. The high melting point of silica enables it to be used in such applications. Crystalline silica is used in hydraulic fracturing of formations which contain tight oil and shale gas.

IV. POLYETHYLENE

Polyethylene or polythene (abbreviated PE; IUPAC name polyethene or poly(methylene)) is the most common plastic. Over 100 million tons of polyethylene resins are produced annually, accounting for 34% of the total plastics market. Its primary use is in packaging (plastic bags, plastic films, geomembranes, containers including bottles, etc.). Many kinds of polyethylene are known, with most having the chemical formula $(C_2H_4)n$. PE is usually a mixture of similar polymers of ethylene with various values of n. Polyethylene is a thermoplastic; however, it can become a thermoset plastic when modified (such as cross-linked polyethylene).

A. Properties

The properties of polyethylene can be divided into mechanical, chemical, electrical, optical, and thermal properties.

1) *Mechanical Properties of polyethylene:* Polyethylene are of low strength, hardness and rigidity, but have a high ductility and impact strength as well as low Friction. It shows strong creep under persistent force, which can be reduced by addition of short fibers. It feels waxy when touched.
2) *Thermal Properties:* The commercial applicability of polyethylene is limited by its comparably low melting point. For common commercial grades of medium- and high-density polyethylene the melting point is typically in the range 120 to 180 °C (248 to 356 °F). The melting point for average, commercial, low-density polyethylene is typically 105 to 115 °C (221 to 239 °F). These temperatures vary strongly with the type of polyethylene.
3) *Chemical Properties:* Polyethylene consists of nonpolar, saturated, high molecular weight hydrocarbons. As a result, its chemical conduct is much like paraffin. The person macromolecules should not covalently linked. On the grounds that of their symmetric molecular structure, they have an inclination to crystallize; overall polyethylene is partially crystalline. Higher crystallinity raises density and mechanical and chemical balance. Most LDPE, MDPE, and HDPE grades have best chemical resistance, that means they don't seem to be attacked by robust acids or strong bases, and are immune to smooth oxidants and reducing dealers. Crystalline samples do not dissolve at room temperature. Polyethylene (rather then cross-linked polyethylene) in general can also be dissolved at expanded temperatures in fragrant hydrocarbons equivalent to toluene or xylene, or in chlorinated solvents reminiscent of trichloroethane or trichlorobenzene. Polyethylene absorbs nearly no water. The gas and water vapour permeability (simplest polar gases) is curb than for most plastics; oxygen, carbon dioxide and flavorings alternatively can go it readily. PE can come to be brittle when exposed to sunlight, carbon black is most likely used as a UV stabilizer. Polyethylene burns slowly with a blue flame having a yellow tip and offers off an odour of paraffinThe material continues burning on removal of the flame source and produces a drip. Polyethylene cannot be imprinted or bonded with adhesives without pretreatment. High strength joins are readily achieved with plastic welding.
4) *Electrical Properties of Polyethylene:* Polyethylene is a good electrical insulator. It offers good electrical treeing resistance; however, it becomes easily electrostatically charged (which can be reduced by additions of graphite, carbon black or antistatic agents).
5) *Optical Properties:* Depending on thermal history and film thickness PE can vary between almost clear (transparent), milky-opaque (translucent) or opaque. LDPE thereby owns the greatest, LLDPE slightly less and HDPE the least transparency. Transparency is reduced by crystallites if they are larger than the wavelength of visible light.

V. CLASSIFICATION OF POLYETHYLENE

Polyethylene (PE) is being increasingly used in many industrial and biomedical applications. Its outstanding features such as regular chain structure, combination of low cost and low energy demand for processing, excellent biocompatibility, and good mechanical properties make PE expand its application continuously [1–5]. The superiority of PE products over metal products is attributed to their light weight, high corrosion resistance, and low costs. However, there are some drawbacks with Polyethylene including low environmental stress cracking resistance, low creep resistance, and poor compatibility with various additives which restricted its use for cretin purposes [6, 7]. Therefore, there have been many attempts to improve the properties of polyethylene by blending it with organic or inorganic material. Polyethylene is classified by its density and branching. Its mechanical properties depend significantly on variables such as the extent and type of branching, the crystal structure, and the molecular weight. There are several types of polyethylene:

1) *Ultra-high-Molecular-Weight Polyethylene (UHMWPE)* - UHMWPE is polyethylene with a molecular weight numbering in the millions, usually between 3.5 and 7.5 million amu. The high molecular weight makes it a very tough material, but results in less efficient packing of the chains into the crystal structure as evidenced by densities of less than high-density polyethylene (for example, 0.930–0.935 g/cm3). UHMWPE can be made through any catalyst technology, although Ziegler catalysts are most common. Because of its outstanding toughness and its cut, wear, and excellent chemical resistance, UHMWPE is used in a diverse range of applications.
2) *High-Density Polyethylene (HDPE)* - HDPE is defined by a density of greater or equal to 0.941 g/cm3. HDPE has a low degree of branching. The mostly linear molecules pack together well, so intermolecular forces are stronger than in highly branched polymers. HDPE can be produced by chromium/silica catalysts, Ziegler–Natta catalysts or metallocene catalysts; by choosing catalysts and reaction conditions, the small amount of branching that does occur can be controlled. These catalysts prefer the formation of free radicals at the ends of the growing polyethylene molecules. They cause new ethylene monomers to add to the ends of the molecules, rather than along the middle, causing the growth of a linear chain. HDPE has high tensile strength. It is used in products and packaging such as milk jugs, detergent bottles, butter tubs, garbage containers, and water pipes. One-third of all toys are manufactured from HDPE.
3) *Cross-Linked Polyethylene (PEX or XLPE)* - PEX is a medium- to high-density polyethylene containing cross-link bonds introduced into the polymer structure, changing the thermoplastic into a thermoset. The high-temperature properties of the polymer are improved, its flow is reduced, and its chemical resistance is enhanced. PEX is used in some potable-water plumbing systems because tubes made of the material can be expanded to fit over a metal nipple and it will slowly return to its original shape, forming a permanent, water-tight connection.
4) *Medium-Density Polyethylene (MDPE)* - MDPE is defined by a density range of 0.926–0.940 g/cm3. MDPE can be produced by chromium/silica catalysts, Ziegler–Natta catalysts, or metallocene catalysts. MDPE has good shock and drop resistance properties. It also is less notch-sensitive than HDPE; stress-cracking resistance is better than HDPE. MDPE is typically used in gas pipes and fittings, sacks, shrink film, packaging film, carrier bags, and screw closures.
5) *Linear Low-Density Polyethylene (LLDPE)* - LLDPE is defined by a density range of 0.915–0.925 g/cm3. LLDPE is a substantially linear polymer with significant numbers of short branches, commonly made by copolymerization of ethylene with short-chain alpha-olefins (for example, 1-butene, 1-hexene, and 1-octene). LLDPE has higher tensile strength than LDPE, and it exhibits higher impact and puncture resistance than LDPE. Lower thickness (gauge) films can be blown, compared with LDPE, with better environmental stress-cracking resistance, but is not as easy to process. LLDPE is used in packaging, particularly film for bags and sheets. Lower thickness may be used compared to LDPE. It is used for cable coverings, toys, lids, buckets, containers, and pipe. While other applications are available, LLDPE is used predominantly in film applications due to its toughness, flexibility, and relative transparency. Product examples range from agricultural films, Saran wrap, and bubble wrap, to multilayer and composite films.
6) *Low-Density Polyethylene (LDPE)* - LDPE is defined by a density range of 0.910–0.940 g/cm^3. LDPE has a high degree of short- and long-chain branching, which means that the chains do not pack into the crystal structure as well. It has, therefore, less strong intermolecular forces as the instantaneous-dipole induced-dipole attraction is less. This results in a lower tensile strength and increased ductility. LDPE is created by free-radical polymerization. The high degree of branching with long chains gives molten LDPE unique and desirable flow properties. LDPE is used for both rigid containers and plastic film applications such as plastic bags and film wrap. The global LDPE market had a volume of almost US$33 billion. The radical polymerization process used to make LDPE does not include a catalyst that "supervises" the radical sites on the growing PE chains. (In HDPE synthesis, the radical sites are at the ends of the PE chains, because the catalyst stabilizes their formation at the ends.) Secondary radicals (in the middle of a chain) are more stable than primary radicals (at the end of the chain), and tertiary radicals (at a branch point) are more stable yet. Each time an ethylene monomer is added, it creates a primary radical, but often these will rearrange to form more stable secondary or tertiary radicals. Addition of ethylene monomers to the secondary or tertiary sites creates branching.

VI. APPLICATIONS OF HIGH DENSITY POLYETHYLENE (HDPE)

Excellent combination of properties makes HDPE an ideal material in diverse applications across industries. It can be engineered according to the end use requirements. HDPE is widely used in ropes, fishing and sport nets, nets for agricultural use, Industrial and decorative fabrics, etc. Other applications of HDPE include pipes and fittings (pipes for gas, water, sewage, drainage, sea outfalls, industrial application, cable protection, steel pipe coating, large inspection chambers and manholes for pipe sewage etc.) due to its excellent resistance to chemical and hydrolysis, automotive – fuel tanks, wiring & cables – sheeting of energy, telecommunication cables. High Density Polyethylene is used in several packaging applications including crates, trays, bottles for milk and fruit juices, caps for food packaging, jerry cans, drums, industrial bulk containers etc.

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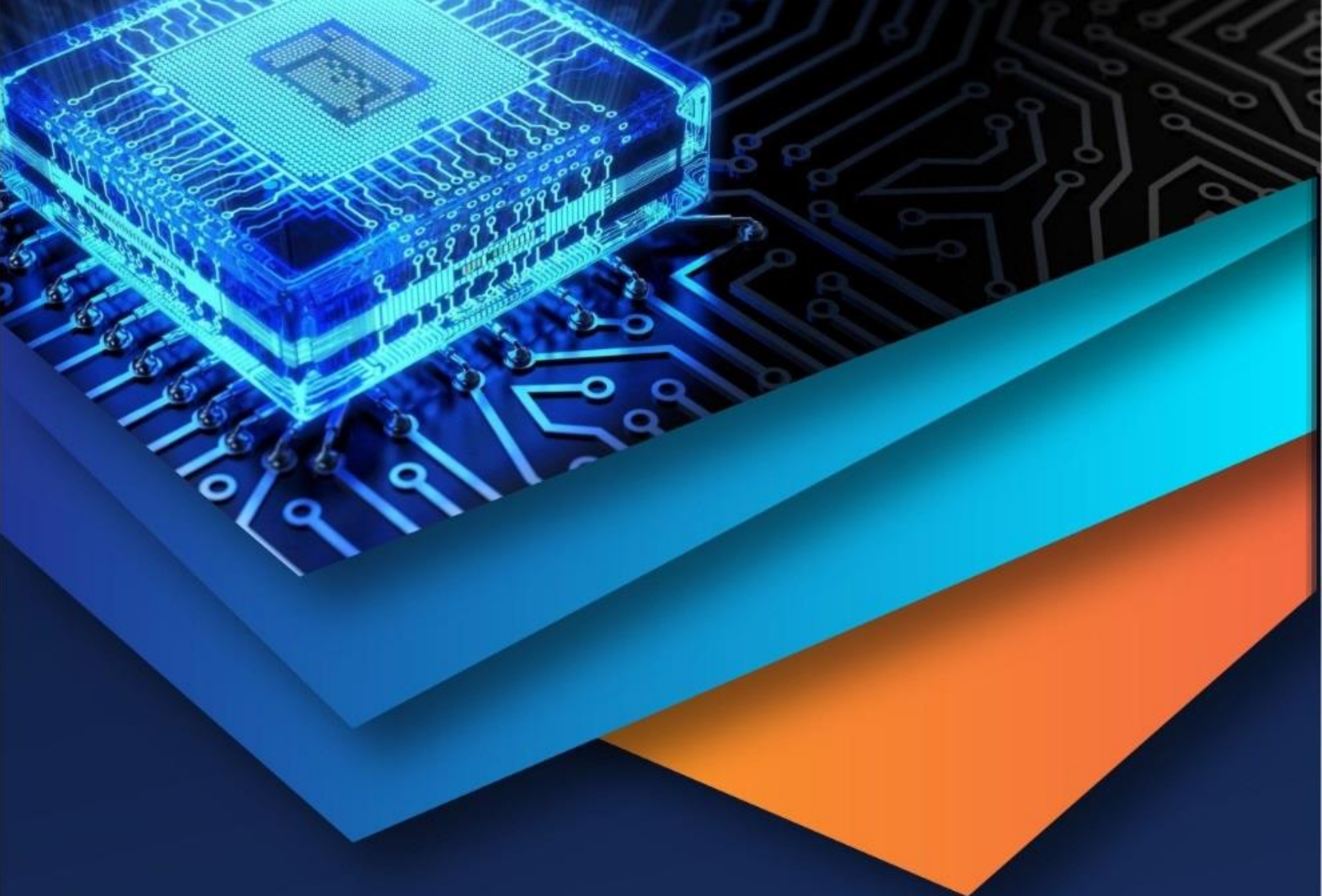

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