A COMPARATIVE STUDY OF HIGH-DENSITY POLYETHYLENE (HDPE) WITH DIFFERENT POLYMER NANOCOMPOSITES CONTAINING SOME COMMON NANOCLAYS IN DIFFERENT COMPOSITION

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ABSTRACT

Scientists and Researchers from all over the world are collaborating to develop innovative compounds that can improve the ecological performance of finished goods and should be eco-friendly. Composites made from natural fibres offer an alternative to synthetic materials that are harmful for the environment and help reduce pollution. Additionally, they are inexpensive, have superior mechanical qualities, and use little energy during production. The polymer Nano composites materials are made of reinforcing material with nanometre-sized filler particles and polymer as the matrix material. These substances have various physical and chemical characteristics, and when combined, they produce Nano composites with special qualities. The polymer matrix consists of high-density polyethylene (HDPE) was used and some common nanoclays used as reinforcements include Rice Husk Ash Hybrid (RHA), Cloisite (30B), Cloisite (25A), and Montmorillonite (MMT). These nanoclay compositions contain between 4% and 0% HDPE reinforcement. In order to improve HDPE's adherence to nanoclay, HDPE was grafted with Maleic Anhydride (HDPE-g-MA) to make it more compatible with other materials. In the present study different nanocomposites were made and their comparative study was done. After that different specification and characteristics were studied and compared for getting a best nanocomposite. Several nanoclays with different Nano composites concentrations have their tensile strengths compared. A variety of nanoclays/high-density polyethylene (HDPE) blends were tested to determine which measured the hardest (in terms of D shore hardness) and was most resistant (in terms of Izod impact strength).

Keywords: Nano composites; Cloisite 30B; Cloisite (25A); Montmorillonite; flexural strength; High Density Polyethylene; Rice Husk Ash Hybrid; tensile; blending; hardness, and impact.

1. INTRODUCTION

A "polymer" is a molecule with a large relative molecular mass and the qualities that come with it since its structure is formed of many repeating units. Greek poly means "many" and mer means "parts." Polymers construct their fundamental building blocks from monomers, which are subsequently replicated along the length of the polymer. For eg. the ethylene monomer is found 'n' times along the polyethylene chain. Polymers can be found everywhere from everyday kitchenware to cars, heavy machinery to satellites, airplanes, and medical and surgical tools as

well as human body also contains a variety of polymers, including keratin in the hair and nails and deoxyribonucleic acid in the nucleus of every cell. Polymers have unique properties, and they depend on the molecules being attached or bonded to one another. Some of the polymers have bending and stretching properties, while the other polymers have glass like properties. There are a lot of polymers; they could have high molecular weights, distinct chemical structures, various physical characteristics, mechanical behaviour, and thermal qualities. The polymers are roughly categorised into two classes; Natural polymers and Artificial polymers. Natural polymers are those that come from living organisms like plants and animals while an artificial polymer is one that has been created in a lab or by a business and can be made from monomer units of organic compounds. Natural polymers include things like starch, cellulose, polysaccharides, nucleic acid, proteins, and even natural rubber and artificial polymer includes polyethylene, polyvinyl chloride (PVC), polystyrene, nylon, Bakelite, and Dacron. Polymers were once thought of as insulators, but as conducting polymers demonstrated the ability to conduct electricity, this perception entirely altered, and many researchers began to pay attention. Over the past 20 years, different types of polymers [1, 2] have been emerged like intrinsic conducting polymers or electrically active conjugated polymers. Polymers are studied by a wide variety of specialists, such as organic chemists, polymer scientists, chemists, and theoretical and experimental physicists [3]. The presence of delocalized molecular orbitals may be the cause of the polymer's conductivity.

They are categorised in following categories: Polymer that can conduct ions- Ionically Conducting Polymer, Intrinsically conductive polymers (ICPs) and Polymer composites that conduct electricity.

1.1 STRUCTURE OF POLYMER

Several length scales, from the sub-nanometer to the macroscopic, can be used to characterize the structure of a polymeric material. A polymer's structure can be described after its component monomers have been identified. Therefore, on the scale of a single chain, the microstructure effectively defines the arrangement of these monomers within the polymer. The figure below depicts four primary polymer structures. Some polymers may have a composition that is a hybrid of these basic building blocks. Networked, crosslinked, branching, and linear polymer are the four most common.
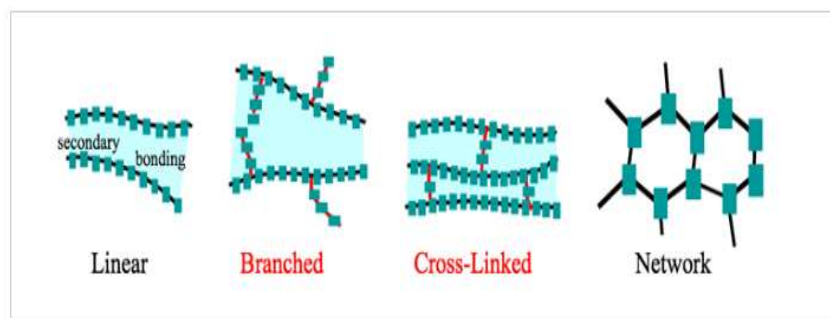

Fig.A. Structure of different polymers

1.2 POLYMER NANO COMPOSITES (PNCs)

PNCs consist of a **polymer or copolymer** matrix in which **nanoparticles or nanofillers** are dispersed. The components of solid polymer Nano composites include a polymeric phase that is the dominant phase and one or more phase-separated elements that include a nano-scale dispersion phase. These nanoparticles can take various shapes, such as platelets, fibers, or spheroids. Depending on the number of dimensions present, these can be broken down into three distinct types: fibers (1D), platelets (2D), and particles (3D). Nano-oxides are used due to their ability to impart features such as self-cleaning, UV protection, and rheological tuning, and some examples include titanium dioxide (TiO2), silicon dioxide (SiO2) and zinc oxide (ZnO). Carbon Nano-tubes and graphene's have some unique features and shapes that increased fabrication efficacy, foremost to extensive obtain-ability at lesser prices.

2. MATERIALS AND METHODS

A composite material is produced while numerous materials having diverse mechanical properties are combined into a single structure. Nanoclay and other Nano-particles can be used to increase a material's dielectric properties, optical and thermal resistance, mechanical attributes (such as strength and stiffness), and durability (resistance to wear and damage). The reinforcing material used to create Nano composites is spread throughout the polymer matrix. nano-particles weight percentage (wt%) may range from 0.5% to 5% of the total mass of a nanoclay. To prepare Nano composites investigated in the present research the following materials were used:

1. High Density Polyethylene (HDPE)

2. Montmorillonite (MMT)

3. Cloisite 30B

4. Cloisite 25A and

5. Cloisite 30B and rice hush ash (RHA) as reinforcement materials.
Montmorillonite (MMT) [4], Cloisite (30B), Cloisite (25A), and Cloisite (30B) combined with Rice Husk Ash (RHA) [5] were all examples of HDPE-enhanced nanoclays. A dual screw extruder was used to blend the nanoclay with HDPE [6]. The Nano composites, which contained anything from 0 to 4% nanoclay by weight, were made by injection molding. All mechanical test specimens were made to exacting ASTM specifications. Tensometer tensile and flexural tests, D shore hardness testing, and an Izod impact tester were just some of the mechanical tests used in the characterizing process.

2.1 PREPARATION OF NANOCOMPOSITES

Nano composites are created using two techniques- Twin screw extrusion is used for compounding and Injection molding is used for mixing [7,8]

2.1.1. EXTRUSION METHOD USING TWIN SCREWS

A number of combinations of nanoclay and HDPE are tried. This method is well-suited to the

extrusion of reactive polymeric substances. Twin screw extruders are very useful pieces of equipment for making hard PVC and wood fiber blends. Extruder settings included a screw speed of 50 rpm and temperature settings of 170, 180, and 190ºC.

2.1.2. PROCESS OF INJECTION MOULDING

The use of an injection molding machine is widespread in the plastics industry. Plastic goods can be made with a variety of different sized and shaped components using injection molding. A mold and materials are prerequisites for the first stage of injection molding. A plastic part is formed when molten plastic is injected into a mold's cavity and allowed to cool and harden.

2.2 METHOD OF FABRICATION

Melt blending was used to combine nanoclays with HDPE in a twin screw extruder; 3 wt.% maleic anhydride was then added to each nanoclays blend. The hopper's top chamber was loaded with nanoclays, HDPE, and HDPE grafted maleic anhydride (HDPE-g-MA). The dual screw, turning at a rate of 120 revolutions per minute, forced the mixture into the hot barrel. The predetermined barrel heat zones were kept at a constant temperature. So, as the plastic beads were being pressed into the barrel, they were allowed to slowly melt. With the pellet cutter, the extruded filament materials were reduced to tiny beads for further processing. Drying the chopped materials in a 60 °C oven for 1 hour reduces their moisture content. As required by the American Society for Testing and Materials (ASTM), the injection molding machine equipped with the appropriate dies produced specimens with excellent flexural, tensile, hardness, and impact test results.

2.3 MECHANICAL TESTING OF NANO COMPOSITES

Specimens for a variety of ASTM-required testing, including tensile, flexural, impact, and hardness, were manufactured [8-10]. Five samples were used for each test, and the average was determined.

I. The Tensile Test: A computerize d 20 kN tensometer was used to perform a tensile test on the materials. Hitech India Equipments Pvt. Ltd. supplied a machine tensometer to Kudale Instruments. This apparatus was used for flexural and tensile testing.

II. The Flexure Test: The flexure test [11] is used to evaluate a material's response to a simple beam loading. "three-point bend test" is a common word used to describe this procedure. Standard ASTM specimens were produced with varying amounts of nanoclay composite, from 0% to 4% by weight, and then subjected to cyclic loading.

III. Hardness: A material's hardness [12] can be quantified by its ability to withstand indentation. The Shore D scale is universally applicable to the determination of the hardness of polymers, elastomers, and rubbers.

3. RESULTS & DISCUSSIONS

Performance Evaluation of Several Nanoclay-Reinforced HDPE Nano Composites were performed and following features like Flexural strength, Flexural Modulus and D shore Hardness No. were studied. After that their comparative study were also performed and the results are also tabulated.

3.1 FLEXURAL STRENGTH

Tensile strength, flexural strength, hardness, and impact resistance tests were conducted on the HDPE matrix both before and after the inclusion of nanoclay particles. The results are shown in Table 3.1. The ability to flex was evaluated with a three-point bend test. Figure 1 displays data showing that flexural strengths tend to occur predictably.

Table 3.1: Flexural Disparity Analysis Nano composites with varying degrees of strength due to nanoclay reinforcement

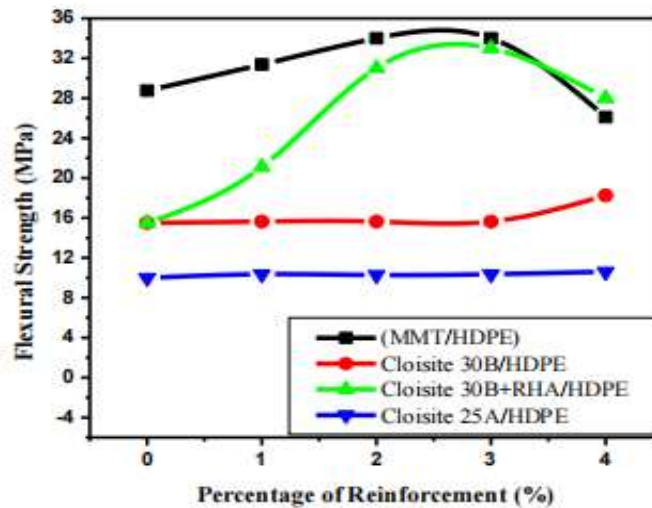| Samples	Flexural Strength (MPa)			
	MMT	Cloisite 30B	Cloisite 30B + RHA	Cloisite 25A
HDPE	28.66	15.5	15.5	10
HDPE+1% Nanoclay	31.38	15.64	21.1	10.36
HDPE+2% Nanoclay	34	15.64	31.0	10.28
HDPE+3% Nanoclay	34	15.64	33	10.36
HDPE+4% Nanoclay	26.1	18.25	28	10.61

Figure 3.1: Flexural Disparity Analysis Nano composites with varying degrees of strength due to nanoclay reinforcement

HDPE reinforced with MMT nanoclay showed a rise in flexural strength as a function of percent wt addition, in line with the expected range of values for flexural strength testing. The effect of Cloisite 30B addition on flexural strength was only marginally significant above 3 wt%

addition. However, when nanoclay was added to Cloisite 25A, its flexural strength was poor in comparison to other reinforcement materials.

3.2 FLEXURAL MODULUS OF DIFFERENT NANOCLAYS

Both the HDPE matrix in its natural state and when reinforced with various nanoclay particles had their flexural moduli measured. Table 3.2 displays the flexural moduli of various nanoclays when not subjected to cyclic stress. These nanoclays include MMT, Cloisite 30B, a hybrid of Cloisite 30B, and RHA reinforced with HDPE.

Table 3.2: Flexural Modulus Evaluation of Various Nano composites Reinforced with Nanoclay

Samples	Flexural Modulus (MPa)		
	MMT	Cloisite 30B	Cloisite 30B + RHA
HDPE	1532	379.23	512.4
HDPE+1% Nanoclay	1137.5	2503.10	1524.5
HDPE+2% Nanoclay	696.76	2844.35	1482.27
HDPE+3% Nanoclay	578.25	1365.4	1235.6
HDPE+4% Nanoclay	1327.1	3716.64	1726.66

At 4 wt% nanoclay reinforcement, cloisite 30B was shown to have a greater flexural modulus compared to other nanoclay reinforcements, with a decrease between 2 wt% and 4 wt%. In Figure 2, we see the average dispersion of flexural strength.
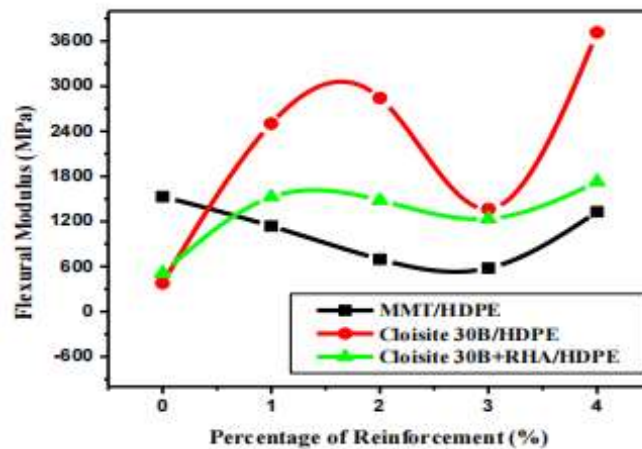

Figure 3.2: Various Nano composites with Reinforced Nanoclay Flexural Modulus

HDPE reinforced with MMT nanoclay exhibited the commonly seen decrease in variance of the flexural modulus with increasing weight addition. Flexural modulus variation increased somewhat with the addition of Cloisite 30B and RHA reinforcement.

3.3 COMPARISON OF HARDNESS NUMBER OF NANO COMPOSITES

Several nanoclays reinforced with HDPE matrices are represented with samples of typical

observed hardness values (D shore hardness) in Table 3.3.

Table 3.3: The variety of Nano composites in terms of D shore hardness.

Samples	D shore Hardness No			
	MMT	Cloisite 30B	Cloisite 25A	Cloisite 30B + RHA
HDPE	48	48	47	47
HDPE+1% Nanoclay	61.3	52.2	54.5	50.5
HDPE+2% Nanoclay	61.8	57.8	58.6	52.7
HDPE+3% Nanoclay	64.6	61.2	63.5	56.8
HDPE+4% Nanoclay	63.9	63.2	66.5	59.8

When compared to both untreated Cloisite 30B and Cloisite 30B treated with rice husk ash, hybrid composites were shown to increase hardness by a higher margin. No noticeable progress could be seen, even after employing a considerably heavier matrix. As can be shown in Figure 4.23, the hardness of all HDPE reinforcing nanoclays is increased when filler materials are added. Figure 3 shows that compared to pure HDPE, the hardness numbers of HDPE/MMT Nano composites are much higher. The increase in hardness with increasing mass may be explained by agglomeration.
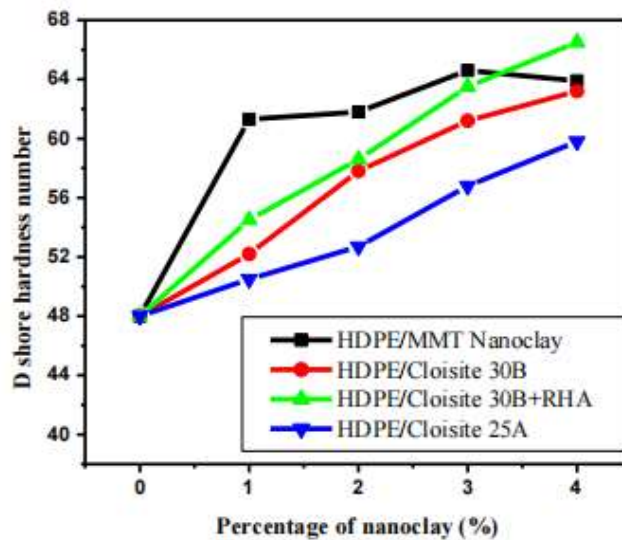

Figure 3.3: Nanoclays reinforcement percentage in high-density polyethylene (HDPE) Nano composites as a function of D-shore hardness

4. CONCLUSION

The current study was aimed to investigate to synthesize different polymer nano composites. Montmorillonite (MMT), Cloisite (30B), Cloisite (25A), and Cloisite (30B) combined with Rice Husk Ash (RHA) were all HDPE-enhanced nanoclays, used for the synthesis of Polymer nano composites. After that the Flexural strength, Flexural Modulus and D Shore Hardness No. of different synthesized nanocomposites were also studied and compaired. It was shown that the inclusion of RHA reinforcement significantly improved the functionality of the

nanocomposite of Closite 30B. After 3600 cycles, the flexural strength of HDPE-reinforced MMT is 36.67 MPa, while the flexural modulus increases by 1 wt% to 2109.3 MPa. Flexural strength and modulus are both improved in the 4wt% hybrid Cloisite 30B with RHA. Among all the Nano composites synthesized for this study it was discovered that MMTHDPE had the best flexural and hardness performance.

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