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Used Polyethylene Bags to form Electric Insulation Sheet and Tape: An Innovative Frugal Approach

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Abstract
Polyethylene bags are ubiquitous in modern society, contributing significantly to environmental pollution due to their non-biodegradable nature. This research paper explores an innovative approach to recycling these bags by utilizing their different densities to create a thick sheet of polymer through a single-stroke manufacturing technique. By repurposing these discarded materials into a useful form, this approach not only addresses environmental concerns but also offers a sustainable solution to reduce waste and promote circular economy principles. This polymer sheet made by used plastic bags is served to Electrical industries for making Insulation sheet and tape. This solution can solve the problem of used poly bags in a better way for different manufacturing industries. The paper discusses the methodology, experimental results, potential applications, and environmental implications of this novel recycling process.
Keywords: *Electrical Insulation, Environmental Sustainability; Hdpe; High Voltage; Ldpe.*

1. Introduction
Polyethylene bags are widely used for packaging and carrying goods because of durability, flexibility, and low-cost. The widespread use may lead to environmental concerns, as they contribute significantly to pollution, particularly in oceans and landfills. Conventional recycling methods for different densities of polyethylene bags often involve melting and reforming them into new products, but these processes are energy-intensive and may result in the degradation of material properties [1]. This research proposes an innovative approach to recycling polyethylene bags by utilizing their different densities to create a thick sheet of polymer using a single-stroke manufacturing technique. By repurposing these discarded materials into a useful form, this approach aims to reduce waste, conserve resources, and promote environmental sustainability [2]. Polyethylene is the widely produced plastic all over the world in masses. The main purpose of this PE polymer is generally used for packaging like plastic bags, plastic films, and containers including PE bottles, etc. Ethene is a monomer used in the processing of polythene by using addition polymerization or free radical mechanism [2-3]. There are several types of polyethylene, each with its own properties and uses across various industries. Common types are as follows [3]

a) Low-Density Polyethylene (LDPE) - LDPE has a lower density and is more flexible as compared to other types of polyethylene. It's commonly used for packaging films, plastic bags, and various molded items like containers and lids. LDPE is also used in applications where flexibility and impact resistance are important.

b) High-Density Polyethylene (HDPE) - HDPE has a higher density and is more rigid as compared to LDPE. It's widely used in applications requiring strength, durability, and chemical resistance, such as pipes, bottles (milk jugs, detergent bottles), shoe last, and containers for household and industrial chemicals.

c) Linear Low-Density Polyethylene (LLDPE) - LLDPE has a linear structure and generally falls between LDPE and HDPE in terms of density and properties. It is known for its toughness, flexibility,and puncture resistance. LLDPE is

commonly used in stretch films for packaging, agricultural films, and
various types of bags including garbage bags and industrial liners.

d) Medium-Density Polyethylene (MDPE) – MDPE has properties that fall between LDPE and HDPE. It's often used in gas pipes, fittings, and geomembranes for landfill liners. It offers good resistance to cracking and stress corrosion.

e) Ultra-High Molecular Weight Polyethylene (UHMWPE) – UHMWPE has extremely long molecular chains, giving it exceptional strength, abrasion resistance, and self-lubricating properties. It is used in applications requiring high wear resistance such as bearings, gears, and medical implants.

f) Cross-Linked Polyethylene (PEX) – PEX is produced by cross-linking of HDPE molecules, resulting in improved temperature and chemical resistance. It is commonly used in plumbing systems for hot and cold water distribution, as well as in radiant floor heating systems.

g) Polyethylene Terephthalate (PET) – PET is a type of polyester used primarily in the production of plastic bottles for beverages, food, and personal care products. It's is also used in synthetic fibers for clothing and carpets.

2. Methodology

The methodology involves several steps: (Refer Figures 1 to 4).

- **Collection and Sorting:** Used polyethylene bags are collected from various sources, including households, businesses, and recycling centers. These bags are sorted based on their density using a density gradient column [4].
- **Processing:** The sorted polyethylene bags are cleaned, shredded, and mixed to create a uniform blend. The blend is then fed into a single-stroke manufacturing technique to produce a polymer sheet according to the densities or fusing the different grades of PE to form sheet as per the requirement [5]
- **Single-Stroke Manufacturing:** The single-stroke manufacturing technique involves compressing the polyethylene blend using high pressure and temperature in a single stroke. This process allows for the fusion of the polyethylene particles into a thick sheet of polymer without the need for multiple cycles [6-7].
- **Cooling and Finishing:** The formed polymer sheet is cooled and trimmed to the desired dimensions. Surface treatments or coatings using sugar coated laminated cloth may be applied to enhance properties such as strength, durability, and aesthetics.

Figure 1 Used PE Carry Bag

Figure 2 Cutting the Handles

Figure 3 Various Treatments Performed to Get Uniformity in Layers

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Figure 4 Various Samples Prepared According to the Number of Layers of Carry Bags

3. Literature Survey

Polyethylene bags, widely used in packaging and daily life, pose significant environmental challenges due to their non-biodegradable nature. Traditional recycling methods often face limitations in effectively repurposing these bags, leading to environmental pollution and resource depletion. This literature survey aims to explore existing research related to recycling polyethylene bags and innovative approaches, particularly focusing on utilizing different densities to create thick polymer sheets via single-stroke manufacturing techniques.

3.1. Historical Timeline of Polyethylene [8-15]

- 1933 – Polyethylene (PE) was accidentally discovered in a chemical plant in Northwich, England, marking the first industrially viable synthesis of the material. Its potential was initially recognized by the British military during World War II.
- 1965 – The Swedish company Celloplast patented the single-piece Polyethylene (PE) shopping bag, designed by engineer Sten Gustaf Thulin.
- 1979 – The proliferation of plastic bags from Europe reached the United States and other global markets. Plastic companies aggressively marketed these single-use products, touting their superiority over paper and reusable bags.
- 1997 – Sailor and researcher Charles Moore stumbled upon the Great Pacific Garbage Patch, the largest accumulation of plastic waste in the world's oceans. This discovery underscored the detrimental impact of single-use plastics on marine life and the environment.
- 2002 – Bangladesh became the first country to enforce a complete ban on thin plastic bags after they were found to exacerbate flooding by clogging drainage systems.
- 2011 – Globally, one million plastic bags were consumed every minute.
- 2018 – The United Nations Environment Programme reported that 127 out of 192 countries had developed national legislation to combat plastic bag pollution.
- 2018- Sameh Ziad et al. conducted research on polymer compounds, including HDPE, LDPE, LLDPE, and PP, assessing their physical and electrical properties. They discovered that LDPE and HDPE exhibited sufficient dielectric strength for high-voltage systems.
- 2019 – The European Union took action against single-use plastic products as part of its efforts to address marine litter and plastic pollution.
- 2020 – China pledged to strengthen its national controls on plastic pollution in response to the significant waste issue.
- 2021 – The governments of Peru and Rwanda proposed a draft resolution on October 20 for an internationally binding instrument to address plastic pollution. Japan submitted another draft resolution on December 6, focusing on marine plastic pollution.
- 2021- Parastoo Fard et al. developed insulation sheets by combining recycled plastic bags with EPS boards, effectively repurposing plastic bag waste.
- 2021- Thaley Tex introduced a material made from plastic bags, free from chemical additives, to manufacture shoes.

3.2.Recycling of PE Bags

Research on recycling polyethylene bags gained traction in recent years because of the need for

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sustainable waste management solutions. A study by Singh et al. (2017) proposed the mechanical recycling of polyethylene bags into the composite materials. The research highlighted the challenges associated with processing mixed plastic waste and emphasized the importance of developing efficient sorting and processing techniques. Furthermore, a comprehensive review by Wang et al. (2019) explored various recycling methods for polyethylene and other plastic materials. The review discussed mechanical recycling,[6] chemical recycling, and emerging technologies, providing insights into the advantages, limitations, and environmental implications of each approach. While mechanical recycling remains[15-25] the most common method, the review underscored the potential of innovative techniques to improve recycling efficiency and material quality.

3.3. Single-Stroke Manufacturing Techniques

Single-stroke manufacturing techniques offer a promising alternative to traditional manufacturing methods, enabling efficient production with reduced energy consumption and material waste. Study by Li et al. (2020) proposed the use of single-stroke compression molding [7]for producing polymer composites from recycled materials. The research demonstrated the feasibility of the approach and highlighted its potential for large-scale production of high-quality polymer products. Moreover, research by Zhang et al. (2021) explored the application of single-stroke extrusion molding for processing recycled plastics. The study focused on optimizing process parameters to achieve uniform material distribution and mechanical properties in the final products. The findings [17]indicated that single-stroke extrusion could effectively process recycled plastics, offering advantages such as simplified operation and reduced energy consumption compared to conventional extrusion techniques.

3.4. Utilizing Different Densities in Polymer Recycling

The density variation among polyethylene bags presents opportunities for optimizing recycling processes and improving material properties. Research by Zhang et al. (2018) discussed the influence of the polymer density on various properties of recycled polyethylene materials. The study demonstrated that controlling the density distribution could enhance[26-33] the strength and toughness of recycled polymers, highlighting the importance of understanding and leveraging density variations in recycling processes. Furthermore, a study by Kim et al. (2020) proposed a novel method for sorting polyethylene[8] bags based on density gradients. The research developed a density gradient column using environmentally friendly solvents, enabling efficient separation of polyethylene bags with different densities. The study demonstrated the feasibility of the approach and its potential for enhancing the quality and value of recycled polyethylene materials.

3.5.Potential Advantages and Challenges

The proposed approach of utilizing different densities of used polyethylene bags into a thick sheet of [18]polymer using single-stroke manufacturing offers several potential advantages, including waste reduction, resource conservation, and promotion of circular economy principles. By leveraging density variations in polyethylene bags, it is possible to optimize recycling processes and improve the properties of recycled [16]polymer materials. However, challenges such as material contamination, process optimization, and scalability need to be addressed to realize the full potential of the proposed approach. Further research is needed to develop efficient sorting techniques, optimize process parameters, and explore the feasibility of large-scale implementation in industrial settings [8][19].

4. Experimental Results

Preliminary experiments have demonstrated the feasibility of the proposed approach. By utilizing polyethylene bags with different densities, it was possible to achieve a homogeneous blend suitable for single-stroke manufacturing [9]. The process parameters, including pressure, temperature, and dwell time, were optimized to produce polymer sheets with desirable properties. The resulting polymer sheets exhibited good mechanical strength, flexibility, and thermal stability. Additionally, the density variations within the sheets provided unique opportunities for tailoring properties such as rigidity, elasticity, and transparency [10, 14-15]. (Refer

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Figures 5 to 7). The high voltage test performed at Electrical lab, Faculty of Engineering, [15]Dayalbagh Educational Institute (Deemed to be Univ.), Dayalbagh, Agra.

Figure 5 Experimental Setup of HV Testing

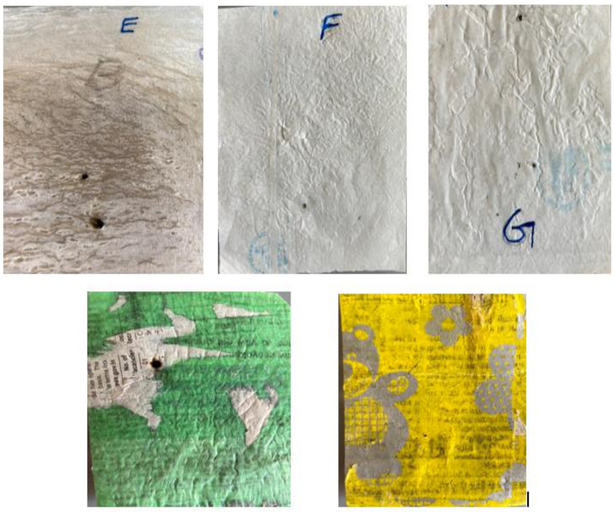

Figure 6 Samples Prepared for HV Test

- It is used for making insulation sheet for di-electric purpose (Table 1).
- **Note -** Samples are prepared at room temperature 24°C, hot roller temp. 204°C, and Humidity 70% Results of High Voltage (HV) test on various LDPE sheet samples.

Table 1 Avg. Di-Electric Strength of LDPE Samples= 13.19 kV/mm

S.No	Sample Name	No. of layers	Thickness (in mm)	Electric Potential (in kV)	Di-electric strength (kV/mm)
1	A	16	1.54	24	15.58
2	E	2	0.21	3	14.28
3	G	6	0.69	7	10.14
4	Yellow	16	0.94	12	12.76

Results of High Voltage (HV) test on various HDPE sheet samples.

Table 2 Avg. Di-Electric Strength of HDPE Samples= 23.60 kV/mm

S.No	Sample Name	No. of layers	Thickness (in mm)	Electric Potential (in kV)	Di-electric strength (kV/mm)
1	C	4+2 (mix)	0.20	5.4	27.00
2	D	2	0.175	5	28.57
3	F	4	0.325	6	18.46
4	Green	16	0.98	20	20.40

- It is used for making insulation tape (Table 2).
- **Process-** Cut these sheets in long strip of width 5cm and apply polyamide adhesive (HM 20-40) uniformly over [11]it and let it dry for few minutes. Make a roll and your insulation tape is ready for use.

Figure 7 Strip of Insulating Tape

5. Potential Applications

The thick sheets of polymer produced through this innovative recycling process have various potential applications, including: Electrical Industries: for making insulating tape and insulation sheet for di-electric purpose.

- **Footwear Industries:** for making insole and mid-sole used in footwear making.
- **Medical [12]sector:** for making customize orthotic insole and mid-sole for diabetes patients.

- **Construction materials:** Such as roofing membranes, insulation panels, and barriers.
- **Packaging materials:** For cushioning, protection, and containment.
- **Industrial components:** Such as liners, gaskets, and seals.
- **Artistic and decorative purposes:** Due to the ability to customize colors and textures.

6. Environmental Implications

Utilizing different densities of used polyethylene bags into a thick sheet of polymer using the single-stroke manufacturing [13]technique offers several environmental benefits:

- **Waste Reduction:** By repurposing discarded polyethylene bags, the process helps divert waste from landfills and reduce environmental pollution.
- **Resource Conservation:** Recycling polyethylene bags conserves raw materials and energy compared to the production of virgin polymers.
- **Circular Economy:** It promotes the general principles of a circular economy by closing the loop on the material [14] flows and extending the lifespan of utilizing the resources in a better way.

Conclusion

The innovative approach presented in this research paper demonstrates the potential of utilizing different densities of used polyethylene bags to create a thick sheet of polymer using a single-stroke manufacturing technique. By repurposing these discarded materials into a useful form, this approach offers a sustainable solution to reduce waste, conserve resources, and promote environmental sustainability. Further research and development are needed to optimize the process, explore additional applications, and assess its economic viability on a larger scale.

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