

**Project title:** Mechanical Recycling of Polyethylene Glycol-Modified Waste: Incorporation of Carbon Nanotubes Towards Functional Composites

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**Introduction & Background:**

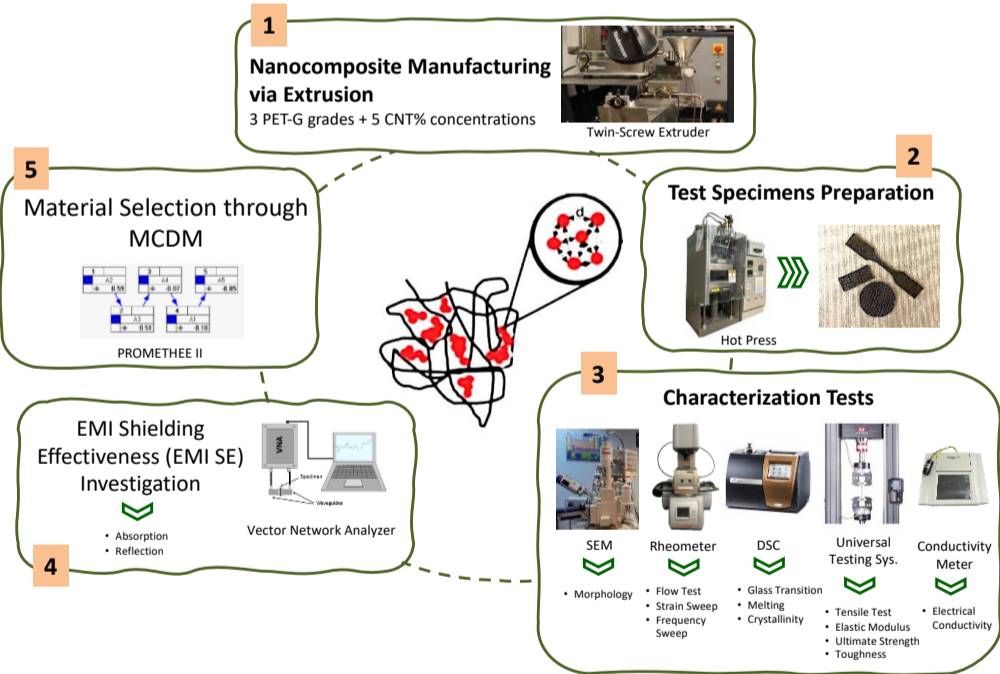
Recent concerns over plastic waste accumulation have intensified research into sustainable recycling methods, particularly for non-biodegradable polymers like polyethylene terephthalate glycol-modified (PET-G) [1]. PET-G's widespread use in packaging, 3D printing, and medical applications has contributed to considerable waste generation, yet its recycling is a significant challenge. This challenge underscores the need for innovative recycling approaches that enhance material recovery and performance. This study explores the mechanical recycling of PET-G by incorporating carbon nanotubes (CNT) to create functional nanocomposites with improved mechanical, electrical, and electromagnetic interference (EMI) shielding properties. The objectives of this research were to develop CNT-reinforced PET-G nanocomposites through twin-screw extrusion and compression molding, optimize processing parameters for uniform CNT dispersion, and evaluate material performance through morphological, mechanical, thermal, and electrical testing. A multi-criteria decision-making (MCDM) approach was employed to identify the optimal formulation, supporting sustainable materials development.

**Relevance to Circular Economy:**

PET-G's limited recyclability leads to waste accumulation, hindering circular economy efforts [1]. This study recycles PET-G by reinforcing it with CNT, creating durable nanocomposites for EMI shielding. Instead of downcycling, which lowers material quality, this approach enhances properties, extending the polymer's lifespan. By reducing plastic waste and reliance on virgin materials, it supports sustainable resource use and waste reduction.

**Methodology:**

The methodology involved fabricating and characterizing PET-G/CNT nanocomposites to assess their rheological, mechanical, thermal, electrical, and EMI shielding properties as shown in **Figure 1**. Three PET-G grades, virgin (V), recycled flakes (rF), and recycled pellets (rP) were used, combined with multi-wall carbon nanotubes (NC7000, Nanocyl) at concentrations of 1–5 wt%. Materials were dried before processing to prevent moisture-induced degradation.



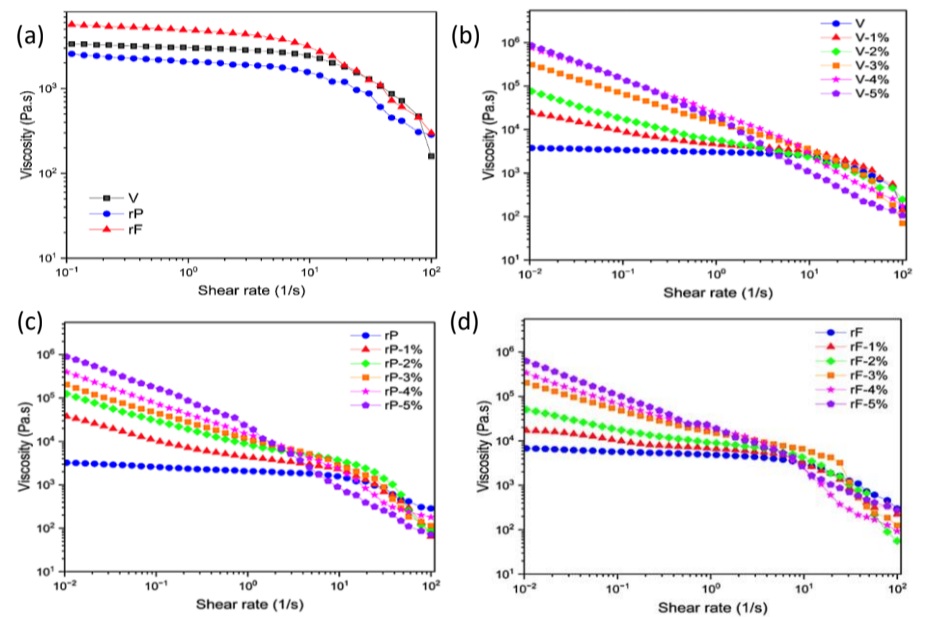
**Figure 1:** Methodology overview.

Nanocomposites were prepared using twin-screw extrusion (Thermo Scientific Extruder) optimized for CNT dispersion, followed by compression molding to form testing specimens under controlled temperature, pressure, and dwell time. Morphological analysis was conducted using scanning electron microscopy (SEM) to evaluate CNT dispersion. Rheological properties were assessed via strain and frequency sweep tests, while differential scanning calorimetry (DSC) measured thermal transitions. Mechanical testing, including tensile strength, modulus, and toughness, was performed following ASTM D638. Electrical conductivity was measured using four-point probe methods, while EMI shielding effectiveness was determined via transmission line technique. A multi-criteria decision-making (MCDM) analysis using the PROMETHEE II method ranked the nanocomposite formulations based on key performance metrics: elastic modulus, electrical conductivity, EMI shielding effectiveness, glass transition temperature, and processability. This approach facilitated the selection of the optimal composition by balancing mechanical performance, electrical properties, and manufacturing feasibility.

**Results & Discussion**

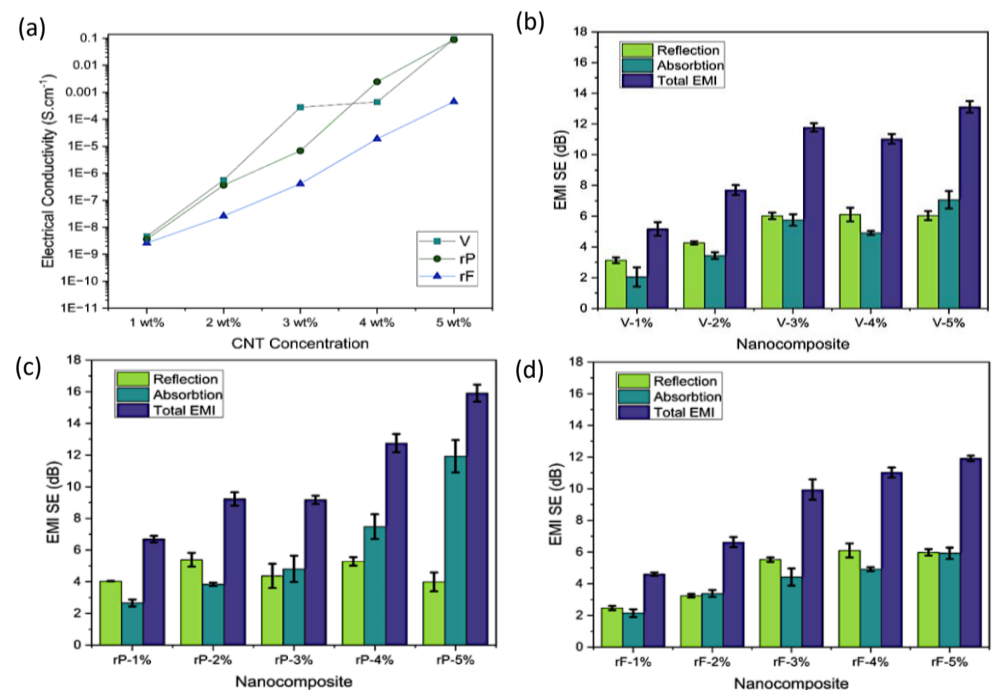
The incorporation of CNT considerably influenced the mechanical, thermal, electrical, and EMI shielding properties of PET-G nanocomposites. Recycled PET-G samples (rP and rF) generally outperformed virgin due to enhanced CNT dispersion. The key findings of this study are as follows:

- As can be seen in **Figure 2**, the addition of CNT increased viscosity across all PET-G grades, with a more pronounced effect in recycled PET-G, where they demonstrated enhanced viscosity, attributed to stronger polymer-filler interactions.
- CNT reinforcement increased elastic modulus and ultimate strength across all samples while reducing toughness.
- EMI shielding effectiveness (SE) was highest in rP-5% CNT composites, as shown in **Figure 3**.
- rP-5% CNT was ranked highest in material selection via MCDM due to superior electrical conductivity, EMI shielding, and balanced mechanical properties.



**Figure 2:** The flow curve of (a) pure PET-G polymers (b) V (c) rP and (d) rF based nanocomposites.

These results demonstrate that recycled PET-G nanocomposites can achieve high-performance properties, reinforcing the potential for sustainable recycling in EMI shielding applications.



**Figure 3:** (a) Electrical conductivity measurements and EMI shielding effectiveness (EMI SE) for (b) V (c) rP and (d) rF based nanocomposites.

**Conclusion & Next Steps**

This study confirmed that CNT-reinforced recycled PET-G, especially rP, offers superior conductivity, strength, and EMI shielding. Future work will optimize processing, explore alternative fillers, and assess scalability for real-world applications.

**References:**

1. Z. O. G. Schyns and M. P. Shaver, "Mechanical Recycling of Packaging Plastics: A Review," Feb. 01, 2021, Wiley-VCH Verlag. doi: 10.1002/marc.202000415.