Stretchable Graphite Fabric for Wearable Energy Storage Applications

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SUMMARY

This project focuses on finding a new sustainable electrode material suitable for wearable energy-storage devices. Different low-cost and flexible carbon-based materials graphite sheet, knitted graphite, and a conductive-ink coated fabric were tested to identify which one shows the best electrochemical performance for future wearable electrode applications.

INTRODUCTION

The market demand for flexible and wearable electronics requires sustainable, high-performance energy storage that can withstand mechanical stress without degrading performance. Conventional materials struggle with capacitance stability and environmental impact. This research investigates three flexible architectures (Knitted Graphite, Graphite Sheet, and Painted Curtain) to find a sustainable, highly stable electrode that maximizes electrochemical surface area and operational lifetime.

METHODOLOGY

Three types of flexible electrodes were prepared: Knitted Graphite, a standard Graphite Sheet, and a textile-based Painted Curtain (where conductive ink was applied to a curtain fabric).Electrochemical Testing: All electrodes underwent cyclic voltammetry (CV) testing using an Na2SO4 electrolyte. Performance Metrics: CV loop area (electrochemical surface area) and specific capacitance were calculated. Stability Assessment: The capacitance of the best-performing electrode (Knitted Graphite) was meticulously tracked for over(15^{th} to 30^{th} cycles) to confirm its long-term operational consistency.

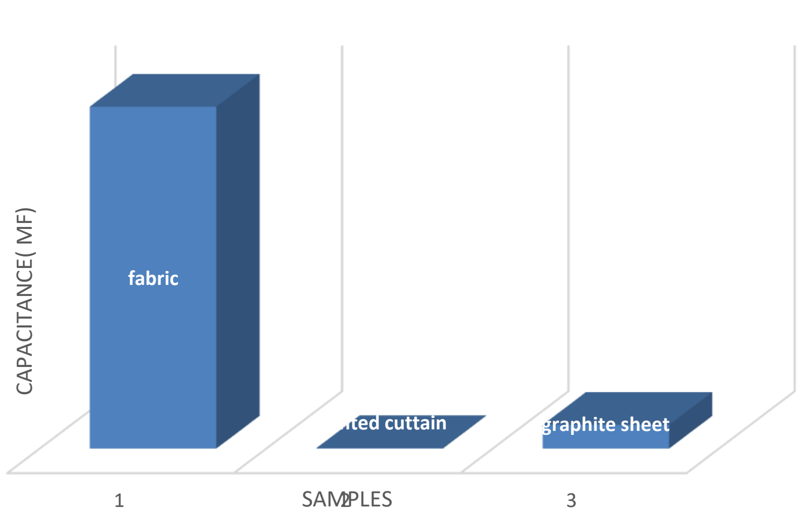

Figure 1. Comparison of capacitance of capacitance of the 3 tested electrodes

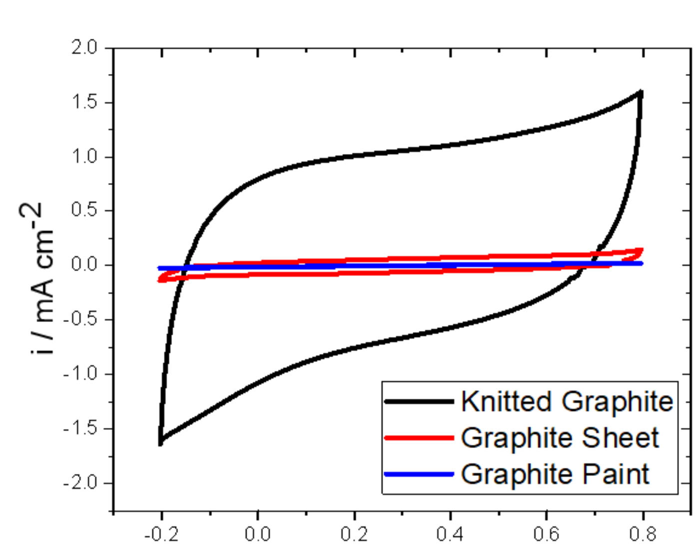

Figure 2. Comparison of cv grpahs of the 3 tested electrodes

CONCLUSION

The Knitted Graphite electrode is the superior and most sustainable flexible material. Its 3D textile architecture delivers both the highest specific capacitance and the most crucial finding: exceptional stability over 30 cycles. The poor performance of the Painted Curtain confirms that a simple surface coating is insufficient. This work validates Knitted Graphite as a durable, sustainable, and high-performance solution ready for integration into next-generation flexible/stretchable energy storage devices.

RECOMMENDATIONS

Based on the highly encouraging results, the following steps are recommended:
Manufacturing Optimization: Focus research on industrial-scale knitting parameters to optimize the porosity and thread diameter for enhanced ion transport kinetics while maintaining low manufacturing costs.
Sustainable Integration: Extend lifespan of the Knitted Graphite electrode.

OBJECTIVE

The primary objective was to compare the electrochemical performance and sustainability profile of three distinct flexible electrode designs to determine the architecture that offers the highest and most stable specific capacitance for integration into flexible energy storage systems.

Figure 3:stretchable knitted graphite

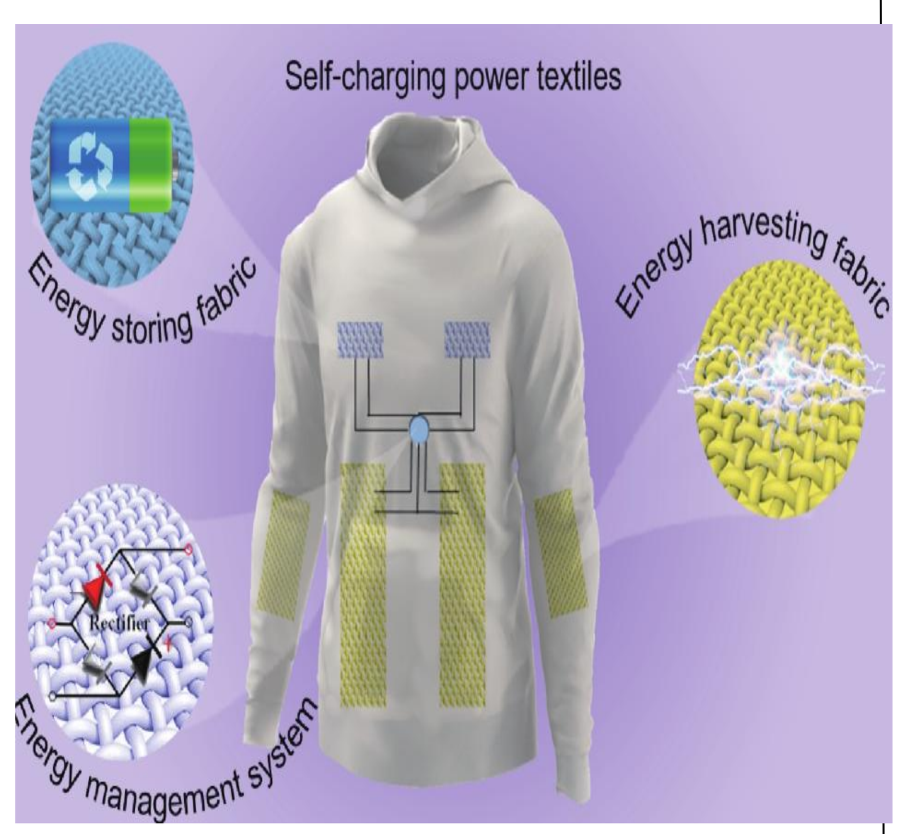

Figure 4:stretchable knitted graphite application

RESULTS/FINDINGS

The study demonstrated a clear link between flexible structure, sustainability, and electrochemical performance:
1. Electrochemical Surface Area (CV) and capacitance analysis
Knitted Graphite: Showed the highest energy storage ability (areal capacitance) because it has high surface area as its inherently three-dimensional, highly porous textile structure, allowing for deep electrolyte penetration.
Graphite Sheet and Painted Fabric: Exhibited low capacitance (energy storage performance,). The limited performance confirms that merely coating a textile substrate restricts ion access and provides insufficient active material mass for effective charge storage.
2. Durability: The fabric's inherent flexibility and the observed electrochemical stability allow for a longer device lifespan, directly reducing material waste and replacement frequency.

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EXPERIMENTAL INVESTIGATION OF THE MECHANICAL AND TRIBOLOGICAL BEHAVIOR OF TiO2-CNT REINFORCED EPOXY COMPOSITES

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SUMMARY

In this study, TiO_2/CNT reinforced epoxy polymer composites were systematically investigated through wear, nanoindentation, tensile, and three-point bending tests to comprehensively evaluate their mechanical, tribological, and deformation behavior.

INTRODUCTION

TiO_2/CNT reinforced epoxy composites are applied in aerospace, automotive, electronics, and structural components where high mechanical strength, stiffness, and wear resistance are required. CNTs enhance load transfer, hardness, and tensile/flexural performance, while TiO_2 improves surface durability and wear resistance, making these composites suitable for lightweight, mechanically demanding applications.

METHODOLOGY

TiO_2/CNT reinforced epoxy polymer composites were fabricated using epoxy resin and hardener, together with TiO_2 nanoparticles and carbon nanotubes (CNTs) as reinforcements. The required amounts of TiO_2 and CNTs were weighed according to the selected weight fractions and added to the epoxy resin. The mixture was initially hand-mixed, followed by mechanical and magnetic stirring to ensure uniform dispersion of the nanoparticles within the resin. After achieving a homogeneous suspension, the hardener was added at the specified resin-to-hardener ratio and mixed thoroughly. The resulting mixture was poured into molds and cured at room temperature to obtain composite specimens for wear, nanoindentation, tensile, and three-point bending tests.

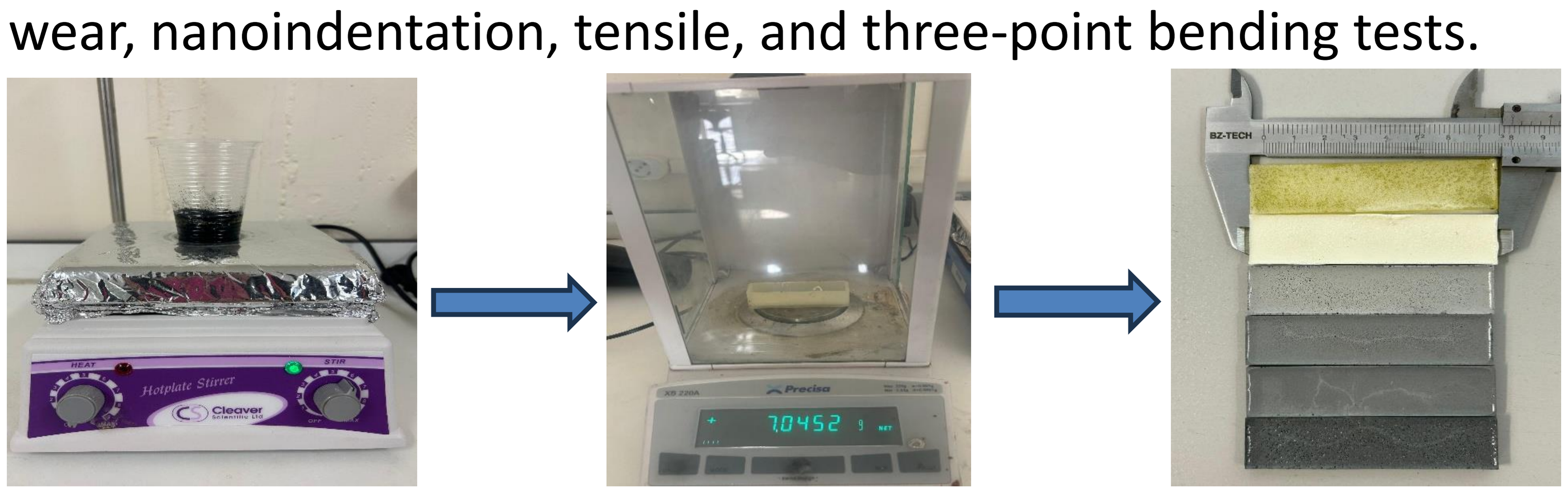

Figure 1. The procedure for producing TiO_2/CNT reinforced epoxy polymer composites

OBJECTIVE

The aim is to assess how different reinforcement ratios affect the composite's mechanical, tribological and structural performance, and to identify the optimum range of hybrid additives.

RESULTS

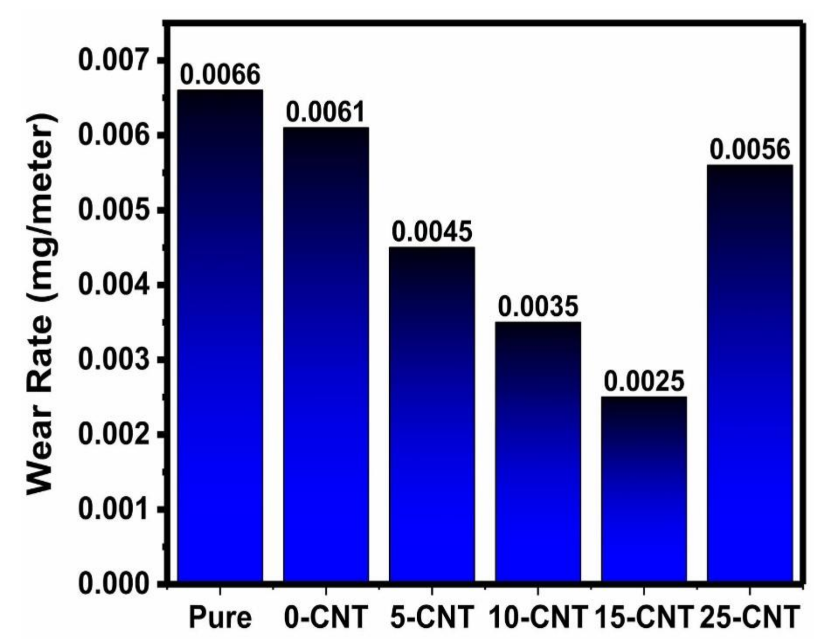

Figure 2. Wear Rate Results

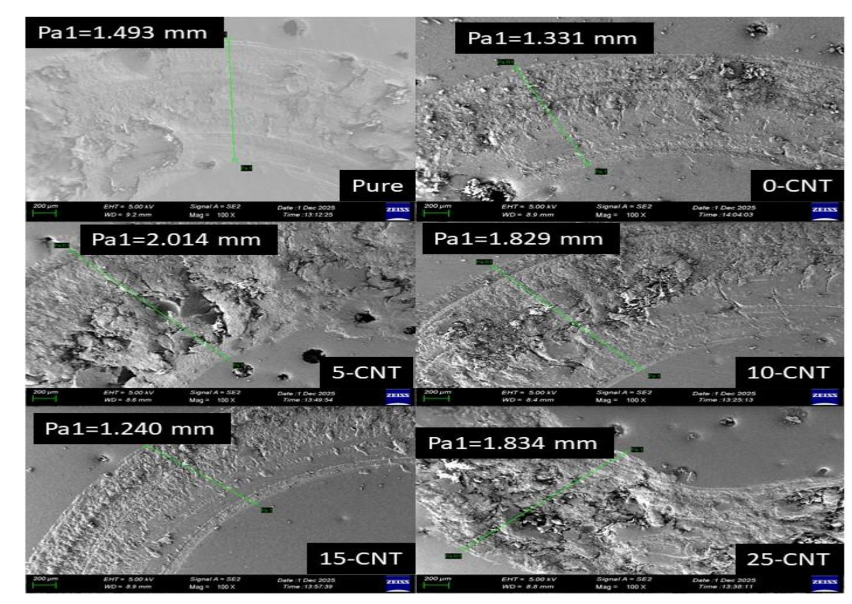

Figure 3. Wear Tracks

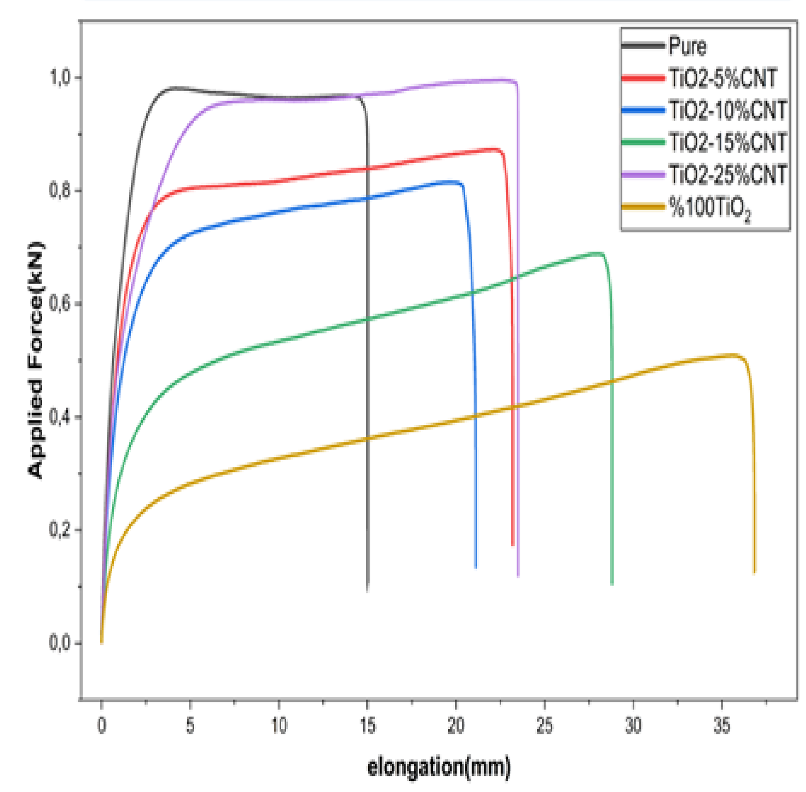

Figure 4. Tensile Test Results

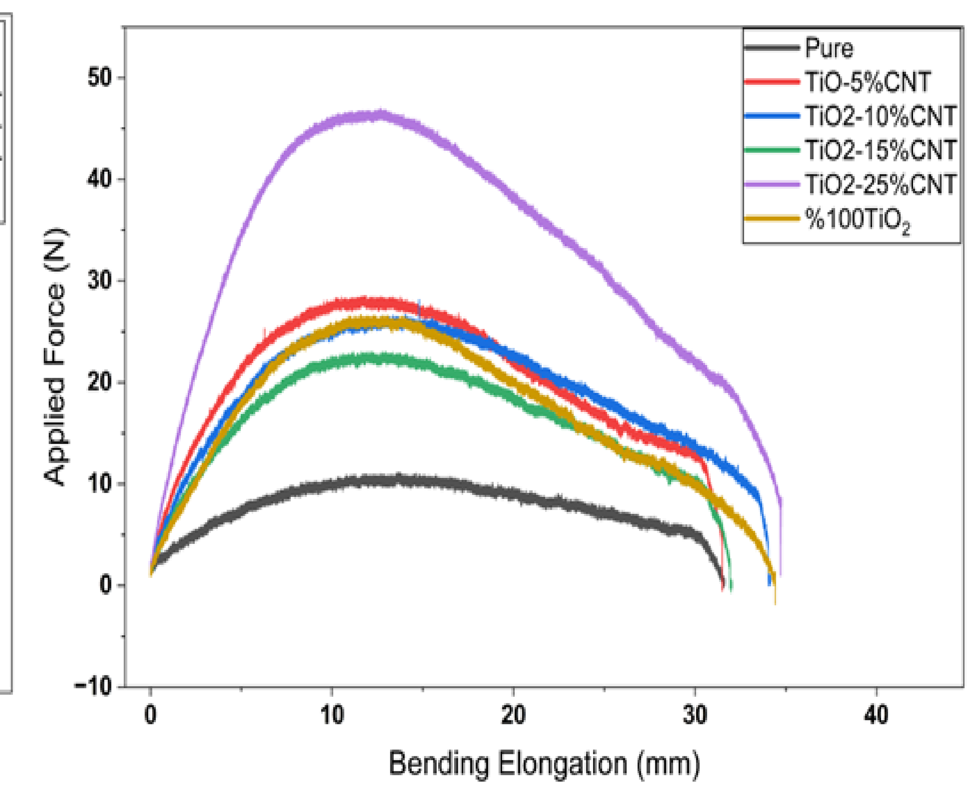

Figure 5. 3-Bending Test Results

Table 1 Nananoindentation Values

Mean	E*[Gpa]	EIT[Gpa]	HIT[Mpa]	HVIT[Vickers]	hc[nm]	hmax[nm]
Epoxy Resine	5.539	4.898	372.145	34.465	1,067.630	1,285.723
100% TiO2	5.881	5.202	480.849	44.532	942.375	1,176.019
TiO2-5%CNT	5.115	4.524	398.315	36.888	1,034.168	1,278.300
TiO2-10%CNT	4.963	4.389	455.058	42.143	973.937	1,242.349
TiO2-15%CNT	3.257	2.880	125.061	11.582	1,865.125	2,083.565
TiO2-25%CNT	5.930	5.245	490.445	45.421	938.388	1,171.729

CONCLUSION

TiO_2/CNT reinforced epoxy composites exhibited improved mechanical and tribological performance compared to neat epoxy. Nanoindentation results showed increased hardness and reduced penetration depth with appropriate CNT content, while wear tests confirmed enhanced wear resistance. Tensile and three-point bending results demonstrated that moderate CNT additions improved load-bearing capacity, whereas excessive CNT content led to property degradation due to agglomeration. Overall, TiO_2–CNT hybrid reinforcement offers an effective approach to tailoring epoxy composites for mechanically demanding and wear-critical applications.

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