

Hypothesis: 100% Hemp-Derived Nanosheet Composite Superior to Graphene-Epoxy

Statement: By integrating hemp-derived carbon nanosheets (HCNS) into a hemp-derived epoxy matrix, it is possible to fabricate a composite material that surpasses conventional graphene-epoxy composites in mechanical performance, sustainability, and economic scalability, due to superior interfacial adhesion, bio-compatibility, and lower environmental impact.

Scientific Basis

Hemp-Derived Carbon Nanosheets (HCNS):

- Produced via controlled pyrolysis and liquid-phase exfoliation of hemp fibers.
- Exhibit high tensile strength, electrical conductivity, and oxygen-containing functional groups enhancing bonding.

Hemp-Derived Epoxy Resins:

- Synthesized from hemp oil and lignin derivatives.
- Naturally compatible with hemp fillers, promoting excellent dispersion and interfacial adhesion.

Advantages Over Graphene-Epoxy

Aspect	Graphene-Epoxy	Hemp-Nanosheet-Hemp-Epoxy
Sustainability	Petroleum epoxy, graphene from graphite	100% hemp biomass sourced
Mechanical Strength	High, but limited by poor filler dispersion	Potential for superior stress distribution
Interfacial Adhesion	Requires chemical functionalization	Naturally high compatibility
Cost & Scalability	Expensive, resource-intensive	Scalable via industrial hemp waste valorization
Toxicity / Safety	Graphene dust toxicity concerns	Non-toxic biomass origin
Lifecycle CO ₂ Impact	Carbon footprint from synthetic processes	Carbon-negative (hemp captures CO ₂)

Critical Success Factors

1. **Nanostructure Control:** High aspect ratio, few-layer nanosheets (<10 nm thickness).
2. **Resin Crosslinking Optimization:** Curing parameters to maximize stiffness and toughness.
3. **Load Transfer Efficiency:** Bio-chemical affinity enhancing interfacial shear strength.
4. **Scalable Fabrication Methods:** Industrial-scale dispersion using eco-friendly processes.

Experimental Validation Roadmap

Phase	Goal	Methods
1. Material Sourcing	Produce hemp-derived nanosheets & bio-epoxy	Pyrolysis, liquid-phase exfoliation, bio-epoxy synthesis
2. Composite Fabrication	Fabricate test panels with varying HCNS loads	Hand lay-up, vacuum infusion with 0.1–5% nanosheet loading
3. Mechanical Testing	Measure tensile, flexural, impact strengths	ASTM D638 (tensile), D790 (flexural), D256 (impact)
4. Microstructural Analysis	Evaluate dispersion and bonding	SEM, TEM, Raman spectroscopy
5. Comparative Benchmarking	Compare vs commercial graphene-epoxy	Direct mechanical property comparison

Laboratory Protocol: Hemp Nanosheet-Hemp Epoxy Composite

Materials Needed:

- Industrial hemp bast fibers
- Organic solvents (e.g., ethanol, acetone)
- Deionized water
- Nitrogen gas (for inert atmosphere)
- Hemp oil (cold-pressed, unrefined)
- Lignin (industrial byproduct)
- Epichlorohydrin (bio-based, if available)
- Curing agents (amine-based, bio-friendly)

Equipment:

- Tube furnace with inert gas flow
- Ultrasonicator or high-shear mixer
- Ball mill (optional for finer particle size)
- Vacuum infusion setup or hand lay-up tools
- SEM, TEM, Raman spectroscopy (for analysis)

- Mechanical testing rig (tensile, flexural, impact)

Step-by-Step Protocol:

1. Hemp Carbon Nanosheet (HCNS) Synthesis:

1.1. **Pre-treatment:** - Wash hemp bast fibers with ethanol-water solution to remove impurities. - Dry at 80°C for 24 hours.

1.2. **Pyrolysis:** - Place dried fibers in a tube furnace. - Heat to 500–700°C under nitrogen atmosphere. - Maintain for 2 hours to achieve carbonization.

1.3. **Exfoliation:** - Disperse carbonized hemp in ethanol-water solution. - Sonicate for 1–2 hours to exfoliate into nanosheets. - Optional: Ball mill for 6–12 hours for finer nanosheet dispersion. - Filter and dry the nanosheets.

2. Hemp-Derived Epoxy Resin Synthesis:

2.1. **Epoxidation:** - React hemp oil with bio-based epichlorohydrin under alkaline conditions. - Maintain reaction at 60–70°C for several hours.

2.2. **Lignin Integration:** - Dissolve lignin in a small volume of solvent. - Mix into the epoxidized hemp oil resin to improve rigidity and crosslink density.

2.3. **Resin Preparation:** - Mix curing agents into the hemp-epoxy resin per stoichiometric ratios.

3. Composite Fabrication:

3.1. **Nanosheet Dispersion:** - Gradually add HCNS into the resin matrix (loading range: 0.1% to 5% wt). - Use ultrasonication or high-shear mixing to ensure homogenous dispersion.

3.2. **Composite Molding:** - Apply resin-HCNS mixture onto mold surfaces (hand lay-up) or perform vacuum infusion. - Ensure air removal to prevent voids.

3.3. **Curing Process:** - Cure composites at ambient temperature for 24 hours, followed by post-cure at 80°C for 2 hours.

4. Testing and Analysis:

4.1. **Mechanical Testing:** - Perform tensile (ASTM D638), flexural (ASTM D790), and impact tests (ASTM D256).

4.2. **Microstructural Analysis:** - Analyze fracture surfaces via SEM. - Validate nanosheet dispersion using TEM and Raman spectroscopy.

5. Benchmarking:

- Compare mechanical properties to industry-standard graphene-epoxy composites.
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Next Steps:

1. Prototype HCNS + Hemp-Epoxy panels.
 2. Develop a ballistic & structural test matrix for defense applications.
 3. File Open Source Prior Art declaration to prevent monopolistic patents.
 4. Prepare funding proposals for scaling Seshat's Composites.
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Prepared by: Marie Seshat Landry — Marie Landry's Spy Shop | 2025