Nanocarbon Enhancement for Aerospace Solutions
Electrically Conductive Polymers
Haydale Global Footprint

- **Locations**: 6
- **Reactors**: 11
- **Staff**: 79
- **Income**: £4.2m
- **Order book**: £5.5m

*Y/E and as at 30 June 2018

Tier 1 member of GEIC

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Company overview

What we do

Increase technical performance and reduce cost across a multitude of industries.

Graphene and other Nanomaterials

1. Produce tailored advanced materials
2. Manufacture unique, proprietary silicon carbide fibres and whiskers
3. Offer graphene enhanced polymers for additive manufacturing
4. Develop graphene enhanced resins for prepreg carbon fibre market
5. Formulate proprietary graphene based inks and coatings

Benefits

1. **Enhance the quality and performance** of our customers’ products
2. **Strengthen ceramics** and enable highly scratch and wear resistant coatings
3. **Better products** with reduced production times
4. **Deliver enhanced electrical, thermal or mechanical performance** to hi-tech industries
5. **Reduce cost and improve data quality**, including regulatory approved ink for biomedical sensors

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Our expertise: Functionalisation

Addition of gases to provide end group functionalisation. i.e. COOH, NH₃, O₂, F, Ar, N₂

Central electrode

Rotating drum containing nanomaterials

Nano materials falling through the plasma

Nanocarbons, including: Graphene, CNTs

Plasma
Company overview

**Our expertise: Composites**

We develop cost effective, tailored fibre reinforced composites for volume manufacture across multiple industries and sectors.

**Performance Improvements**

**ELECTRICAL CONDUCTIVITY**

**Benefits**
- Enhanced lightning strike protection
- Enhanced conductivity

**Applications**
- Electronic cases and enclosures
- Conduits and cables
- Antennas
- Reflectors

**THERMAL CONDUCTIVITY**

**Benefits**
- Enhanced thermal conductivity

**Applications**
- Wind turbine blades
- Pressure vessels
- Pipes
- Mould tools

**MECHANICAL STRENGTH**

**Benefits**
- Improved fracture Toughness
- Improved impact resistance
- Improved compression after impact

**Applications**
- Ailerons, Leading edges, Cowlings F1, Rally, bodywork
- BAC Mono, Rackets, hockey stocks, helmets, bike frames
We are a trusted partner to our customers, putting quality, performance and customer service at the heart of everything we do.

**AEROSPACE**
increased through thickness electrical conductivity by 600%

**AUTOMOTIVE**
stronger, lighter and more fuel-efficient vehicles

**SPORT**
transformed sports equipment

**MARINE**
towards weight reduction and increased strength

**MEDICAL**
optimised graphene inks for biosensor devices

**PRINTING & COATINGS**
scratch resistant coatings with enhanced thermal response
SPECIFIC CHALLENGE:
Lightning strike protection with minimal parasitic mass
Lightening strike protection requirements for civil aerospace

Composite Materials development

- Further develop knowledge of the material properties that drive performance in lightning strikes protection of aircraft structures.
- Use a system approach to composite material development – develop the bulk resins and intra-laminate distribution of conductivity.
- Baseline against the current A350 and/or Eurofighter Typhoon materials, lightning strike surface protection, and paint system.
- Also leads to development of composite materials for electronics enclosures, electro-static discharge, and electromagnetic shielding.
Overview of materials development – electrically enhanced composite prepregs

- Enhancements achieved by modifying the formulation of the resin component of the prepreg.
- The nano-additives (graphene, CNTs, or other nanocarbons) are functionalised for improved dispersion in the resin and improved adhesion to the resins using the HDPlas® low temperature plasma process.
- Cold plasma treatment offers a clean, solvent-free, and scalable technique for functionalising carbon based nanomaterials (European patent EP 2649136).
- A masterbatch of the carrier resin with a concentrated level of nano-additive is prepared by Haydale and we work with processors to deliver finished materials.
Prepreg is the primary material offering that is being developed.

- Highly controllable impregnation of resin into fibre fabrics.
- Increases the uncured stability of advanced resin system for reliable delivery to customer.
- Ensures the high level of materials tractability demanded by aerospace.
Composite Prepreg Manufacture

Effect of additive and functionalisation on resin viscosity

Viscosity

Temperature

Base resin (unmodified)
With nano-additive, functionalisation ‘A’
With nano-additive, functionalisation ‘B’

Prepreg manufacturing process window
Composite Prepreg Manufacture

Laminate electrical conductivity through-the-thickness (0°/90° lay-up)

Comparison of conductivity

- Baseline
- Development material 1
- Development material 2
- Development material 3

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Composite Prepreg Manufacture

Laminate compressive strength (0°/90° lay-up)

Compressive strength (MPa)

Baseline
Development material 1
Development material 2
Development material 3

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Electrifyingly enhanced prepregs

Lightning Strike - Test Setup (courtesy of Cobham)

Accepted lightning strike protection system
- Metallic mesh conductor
- Carbon fibre layers
- Epoxy resin matrix

Development lightning strike protection system
- Carbon fibre layers
- Epoxy resin matrix containing highly-conductive graphene
Electrically enhanced prepregs
Lightning strike tests

Rear Face Damage after testing – control vs Haydale formulation

Standard epoxy control
(no copper mesh)
Damage = 4

Haydale formulation
(no copper mesh)
Damage = 0
Electrically enhanced prepregs
- summary

**Lightning strike protection of composites**

- Nano-additives can greatly improved lightning strike performance with the removal of rear face damage.
- 3 orders of magnitude increase in through-thickness electrical conductivity of laminates with scope to increase by several orders of magnitude more.
- Strength properties equivalent or better than control material
  - 20%+ increase in compression modulus
  - 5%+ increase in in-plane shear modulus
  - 20%+ increase in flexural modulus
- Applications in anti-static and electrostatic discharge areas.
- Application in layered materials – conductive paths in laminated composite structures.
Electrically enhanced prepregs
Demonstrators

4m Aileron from the Airbus Eco-Flyer

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Demonstrating that the new electrically enhanced prepreg can be used to form the complex aerodynamic surfaces of an innovative UAV.
Conductive polymer and composites development theme at Haydale

Nanocarbon additive enhanced thermoset polymers for:

**Electrically conductive adhesives**
- NATEP supported development.
- Targeting aerospace applications but with many cross-sector applications.

**Thermally conductive prepreg**
- Niche Vehicle Network supported development.
- For use in composite tooling applications in aerospace and automotive manufacturing processes.
Thank You

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