Haydale locations

| 5 Locations | 11 Reactors | 50 Staff |

Head Office

- Haydale Composite Solutions
- Haydale Technologies Inc.
- Haydale Korea
- Haydale Technologies (Thailand) Co., Ltd.
Company Overview

HDPlas™ Technology

RAW MATERIALS
- GRAPHENE
- CARBON NANOTUBES (CNTs)
- OTHER NANOMATERIAL

CHEMISTRY
- O₂
- COOH
- NH₃
- F
- Other...

LEVEL
Degree of functionalisation

INTERMEDIATES
- INKS; DISPERSIONS; ETC
- POLYMERS; COMPOSITES; COATINGS; ETC

SURFACE FUNCTIONALISATION

END USES
- TRANSPORTATION; ENERGY;
- OFFSHORE; ELECTRONICS;
- PACKAGING; CONSTRUCTION; MEDICAL;

Epoxy (no filler)
0.5 wt.% NON Functionalised CNTs in epoxy resin

0.5 wt.% Functionalised HDPlas CNTs in epoxy resin
HDPlas™ - The New Era Of Functionalisation

- Oxygen 4% -> 28%
- NH3 2% -> 8%
- Hybrid functionalisation, combining functionality for optimized performance
- Advanced chemistries
- Increased patent coverage
- New material treatments, including plastics
- Scaled production ready plasma reactors
- Sophisticated plasma reactors deliver tunable levels of functional groups
HDPlas™ - Functionalisation USP

- Global raw materials supply chains, over 250 treated materials.
- Cost effective treatments enabling the nano materials markets.
- Environmentally friendly.
- Non-destructive and pristine chemistries.
- Third party verified by National Physical Laboratory (NPL)
- Worldwide patent protection.
- Customizable process & Chemistries to enhance matrix interactions with polymer, water and solvent systems.
Company Overview

HDPlas™ Technology

Sedimentation after 3 hours

Market GO material

HDPlas Treated
High O2
Nitrogen
- Levels trend with treatment levels on both materials.

Oxygen
- FLG2 oxygen levels trend with treatment levels.
- FLG1 appears to have been ‘overtreated’ by Ohigh but further investigation showed different types of side groups affecting oxygen levels. (acidic)
- Furthermore, oxygen plasma can be manipulated to give various ratios of acidic and hydroxyl groups.

Data shows HDPlas® reactors are capable of tuning the levels of both nitrogen and oxygen.
Surface Chemistry changes by Zeta potential

- Zeta potential is a measure of surface charge.
- Different chemical side groups have different effects on surface charge.
- Functionalising the surface of a material changes surface charge without changing other properties.
- High zeta potential (positive or negative) demonstrates good colloidal stability
- Stability is dependant on the charge interaction between liquid and solid.

![Zeta potential @pH3: Nitrogen feed gas](image)

- Shown here that the addition of nitrogen by the plasma process has increased zeta potential at pH3 on both FLG and GNP substrates.
- Both are therefore very stable in acidic solution.

- Alterations to the surface chemistry allows tuneable solubility, thus matching the powder to the required matrix/polymer/liquid.
- Improved surface interaction leads to homogenous dispersions, easier mixing, more concentrated dispersions and slower settling times.
- Proper integration of graphitic nanomaterials has the potential to add the properties of graphite/ene to the finished product.
Company Overview

Haydale Market Sectors

Creating Material Change
Creating Material Change

Composites
Haydale pre preg products are commercial available and now selling across sectors

Generation 2 of pre preg products currently under development, for enhanced thermal, electrical and mechanical performance
Case Study Highlights

• Haydale have been working in collaboration with BAC (Briggs Automotive Company) as part of NVM (Niche Vehicle Network) project.

• The BAC Mono contains the world first graphene enhanced prepreg body panels & were produced using graphene enhanced prepreg tooling.

• Haydale's mechanical prepreg, providing optimised weight savings and mechanical strength enhancements, for the next generation road cars.

• Haydale thermally enhanced prepreg has been developed for the automotive industry, to improve the surface finish of visual panel parts.

• Customer has fed back is that the tooling has a better thermal coefficient, better tool & body panel surface quality & that the parts & tooling are better to machine.
Our technologies / products

Haydale - Mechanical Pre Preg

• Product Highlights
  • Increased Fracture Toughness
  • Impact strength
  • Compression after impact
  • In-plane shear strength
  • Improved fatigue & performance
  • Stiffness improvements
  • Dampening, vibration improvements

• Process Highlights
  ▪ Reduced number of plies
  ▪ Lighter weight components
  ▪ Reduced processing costs
  ▪ Lower component costs
  ▪ Affordable composites
  ▪ Reduced processing time
Creating Material Change

- Lightning strike prevention aircraft/marine
- Electronic cases and enclosures
- Conduits and cables
- Antennas
- Reflectors

Aerospace
Telecoms and Power Utilities
Medical
Defence

Current approach to lightning-strike protection
- Metallic mesh conductor
- Carbon fibre layers
- Epoxy resin matrix

Proposed approach to L-S protection
- Carbon fibre layers
- Epoxy resin matrix containing highly-conductive graphene

Electrical Resistivity

- Resistive
- Anti-static
- ESD, coatings
- Conductive

Lightning Strike - Test Setup (courtesy of Cobham)
Creating Material Change
Functional Inks & Coatings
Our technologies / products

2D Printing

Printing using conductive inks has wide reaching commercial opportunities in electronics, sensors and optical systems.

- Haydale offers and extensive range of world leading, cost effective nano enhanced ink products, but also offer bespoke solutions for customer specifications;

- Functionalised conductive carbon based inks normalised 8 $\Omega/\square/25.4\text{um}$

- Range of Carbon/Sliver Hybrid, adaptable conductivity for application.

- Flexible conductive inks, used for flexible coating and printing systems

- Piezo resistive carbon based inks

- Transparent conductive inks, typical conductive range normalised 50 to 200 $\Omega/\square/25.4\text{um}$

- Specially formulated anti counterfeit inks
Haydale has extensive experience in the treatment of Carbon blacks.

Using Haydale’s functionalisation process allows for large performance gains in the conductivity of Carbon Blacks.

Example below on how Carbon black can be used in flexible printed electronics.

As part of a product development study Haydale treated a powder blend with Carbon Black additives as the primary component. This resulted in a inks product with $140 \, \Omega/cm$.

Plasma functionalisation treatment increased. This resulted in a inks product with $40 \, \Omega/cm$.

Conductive screen printed ink sample containing Carbon Black – Susceptibility study.
Our technologies / products
Haydale Technology Offering

- Functionalized fillers is improved coating fatigue resistance as the tortuous path of graphene platelets coupled with the mechanical properties of graphene also acts to minimize crack propagation, improving coating durability.

- Haydale’s worldwide patented HDPlas functionalisation process, allows for surface modifications to nano fillers to boost the dispersibility and properties of coatings (Mechanically and electrochemically).

- The HDPlas modifications can provide **multi functional** coatings providing improved corrosion protection and hydrophobic properties. Which additionally provides improved mechanical and adhesion qualities.

- Whilst also optimizing formulation compatibility with the chosen polymer systems. Which allows for optimized dispersion for coating systems

![Image](image-url)

Unfilled epoxy resin exhibits poor hydrophobic properties, leading to wetting of surface and potential for microbe accumulation and bio-fouling.

Addition of graphene slightly improves hydrophobicity, although still poor.

Functionalization through HD PLAS process significantly increases hydrophobicity, shown by large decrease in contact angle.

**Fig 1:** Unfilled epoxy on glass  
**Fig 2:** Unfunctionalized graphene enhanced epoxy on glass  
**Fig 3:** Functionalized graphene enhanced epoxy on glass
Our technologies / products

Haydale Technology Offering

Untreated Graphene Coating

HDPlas Treated Graphene Coating
Investigated the dynamic property enhancement of elastomers through HDPlas® nanomaterial incorporation for F1 engine mount compounds

Summary

- Is stronger, tougher & more tear resistant - up to 33% higher tear resistance.

- Offers higher load bearing capabilities – up to 10% higher loads at equivalent deflection.

- Shows improved damping characteristics, despite the higher stiffness - up to 36% higher tan delta relative to control.

- Other key properties are maintained.
Investigated improvements in unfilled and filled natural rubber compounds for railway engine mounts

- Found that nanomaterials incorporated into unfilled and filled compounds can have a significant improvement on the properties of rubber compounds

- Haydale developed a novel process to effectively handle and incorporate nanomaterials into rubber compounds, aiding the dispersion

- Plasma functionalisation can improve the performance of nanomaterials incorporated into rubber compounds

- Only 1 phr nanomaterial can increase stiffness of engine mount by 25%, measured on servo-hydraulic test equipment.

- Bonding to metallics improved vs control
• Haydale can produce a wide range of functionalisation including materials such as High treated oxygen (28% Pure Oxygen Groups)

• The HDPlas™ process can produce pure functionalisation, with no tramp elements such as Sulphur

• Hybrid functionalisation, combining functionality for optimized performance

• HDPlas™ is scalable to production volumes, cost effective to end customers.

• Worldwide patented process

• Produces environmentally friendly non-hazardous materials

• Haydale have evaluated, measured and characterised over 250 different graphene family nanomaterials
Thank you

John-Mark Seymour
Site and Engineering Manager
M: +44 (0) 7896733785
DDI: +44 (0) 1269 843624
Email: john-mark.seymour@haydale.com
www.haydale.com