



Haydale Advanced Materials Graphene Cambridge 5-6 November 2015



THE FUTURE IS... POSSIBLE

Cambridge Graphene Tech Days 2015
3rd CIR Graphene Business Conference
6 November 2015 www.hvm-uk.com

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- Listed on London Stock Exchange 14th April 2014
- Raised £6.6m for expansion in 2014 and on 2nd November a further £6m for commercialisation. Post money valuation is £27m
- Now have centres of excellence in USA and Far East
- Acquired a composites business in November 2014
- Focussed on plasma treatment of nano materials that adds compatible chemical groups to ensure homogeneous dispersion

An enabling technology focussed on

- Composites
- Inks/Paints and technical coatings
- Energy storage

HGI Corporate Video



THE FUTURE IS... POSSIBLE

Graphite

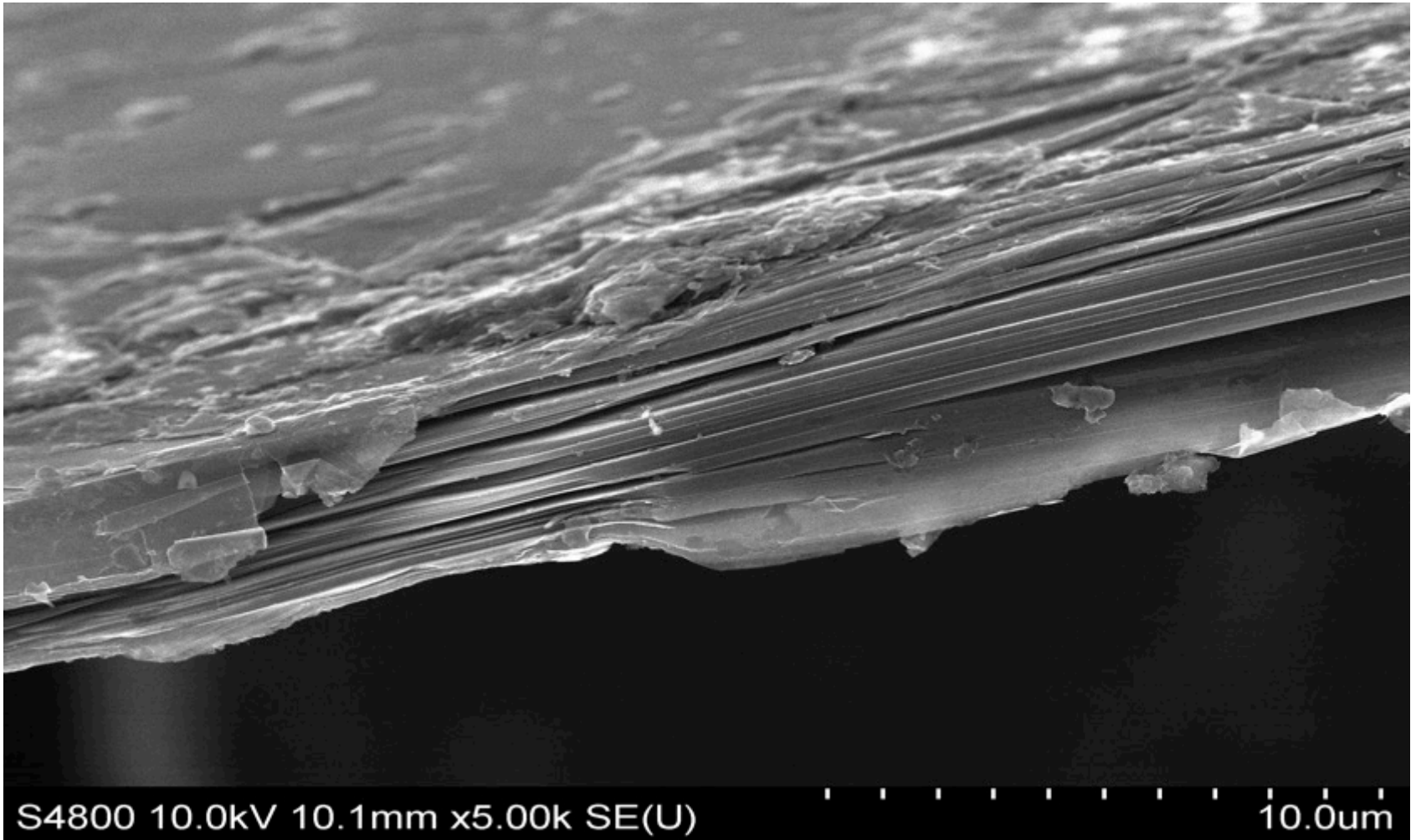
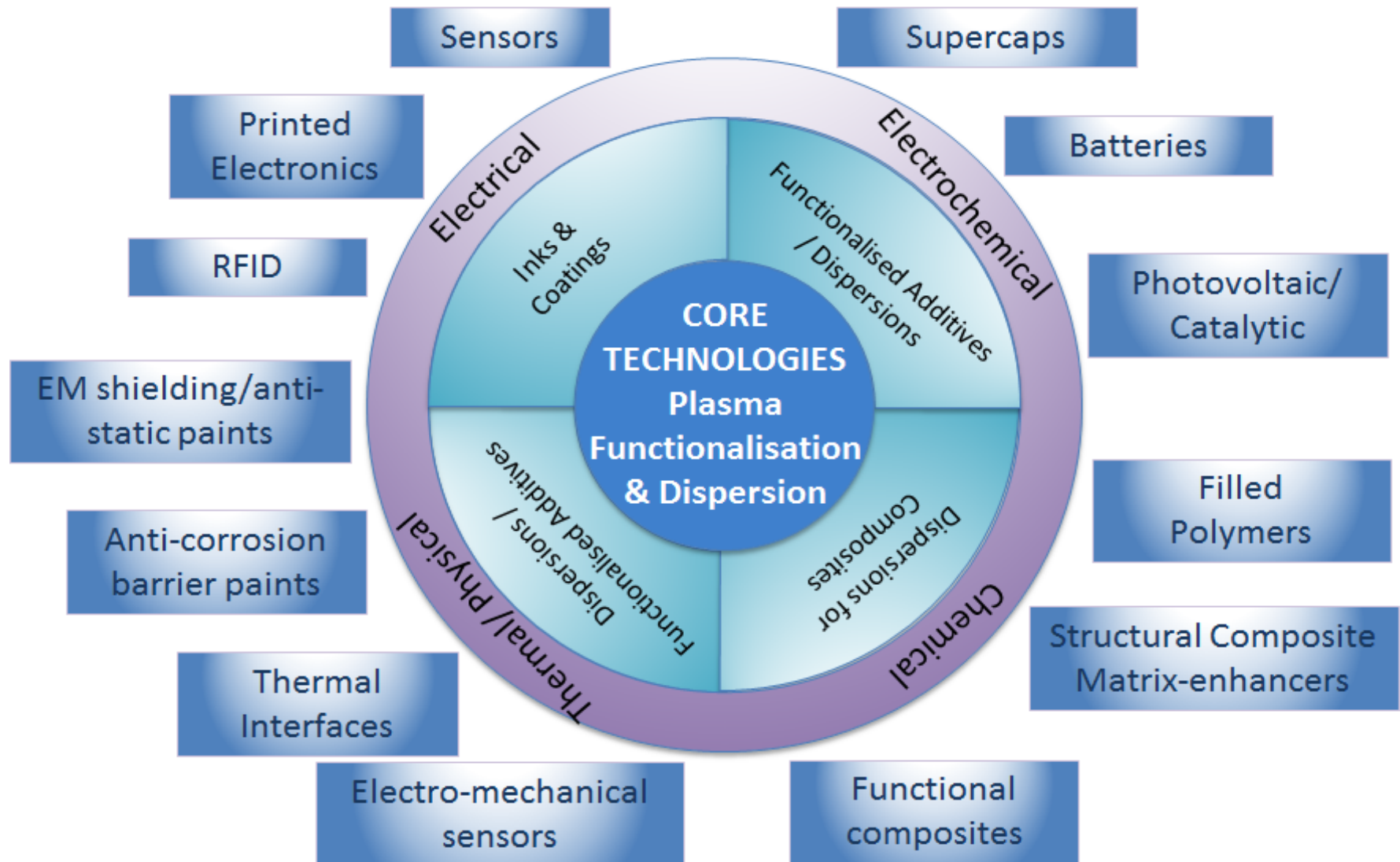


Image taken in Swansea University by Haydale Limited in 2010

THE FUTURE IS... POSSIBLE

The attainable markets today



- **Market currently limited by supply- yes/no:**
 - \$100m by 2018 and \$986.7m by 2022 – estimated, IDTechEX and BCC Research
 - Excludes grant funding- EU €100m pa
 - Significant price variance depending on quality and applications. **Caveat Emptor**
 - Near term material- Graphene Nano Platelet (GNP)
 - GNP market capacity difficult to establish - estimated at +100 tonnes – growing.
- There remains hype and confusion over terminology

The "Graphene" Conundrum



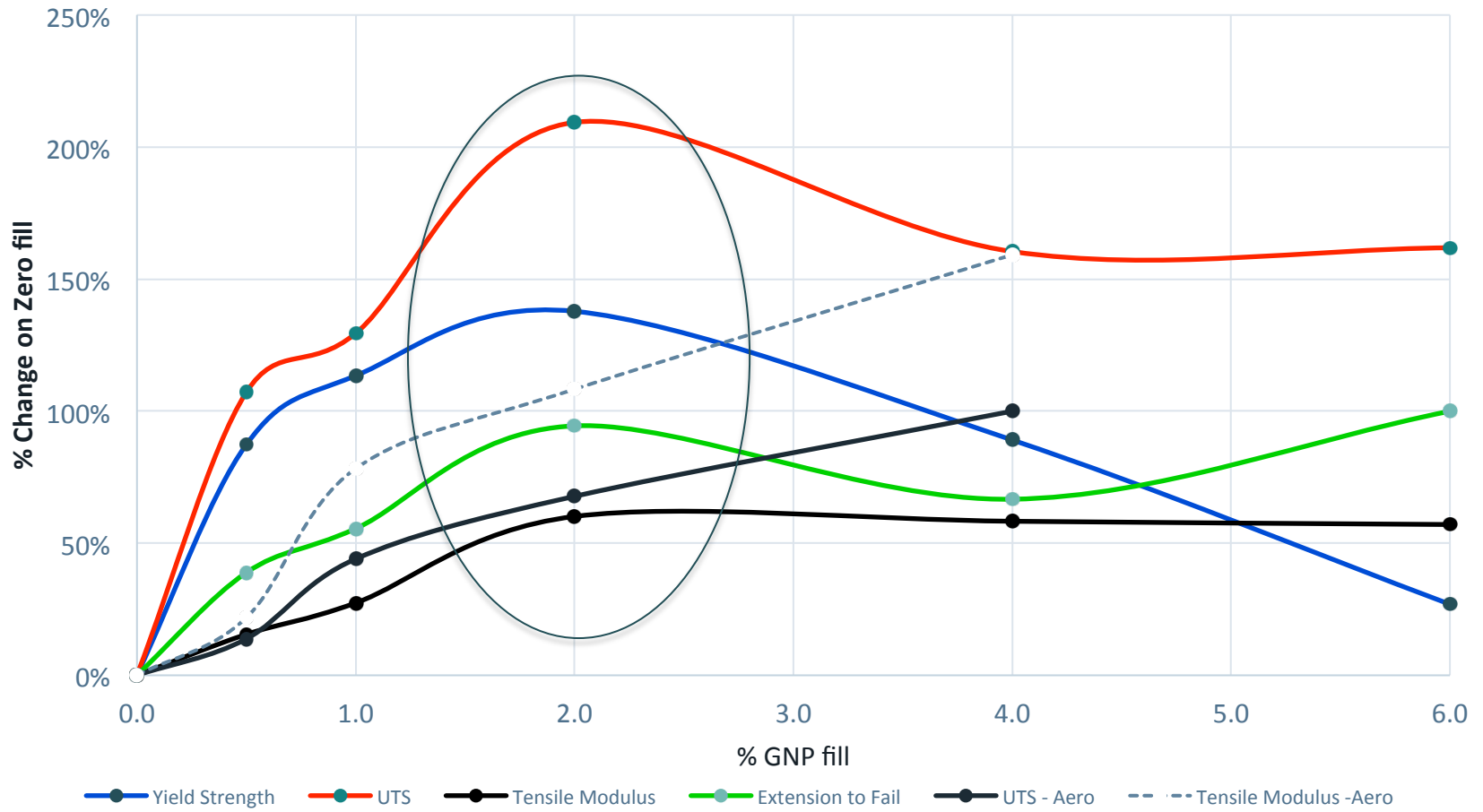
Type	Carbon Layers	Properties/Applications	Typical cost (\$/KG)	Commercially available
Epitaxial CVD	1-2	Conductive/almost Transparent/ITO? High end electronics	High- \$500,000/m ²	CVD systems- Scale up? Cost! ITO?
FLG	3-10	Conductor/flexible/very high surface area/Sensors	200-2,000	Yes- consistency?
GNPs	11-100	Composites/Inks and coatings/ Lubricants/Printing	50-200	Yes- variable product
GO	various	Insulator- semiconductor? Hydrophillic-dispersions Defects and voids	200-2,000	In Part- still evolving
Graphite	100+	Lubricants/Refractories/brakes/ Engineering materials	3-20	Established >90,000mt pa

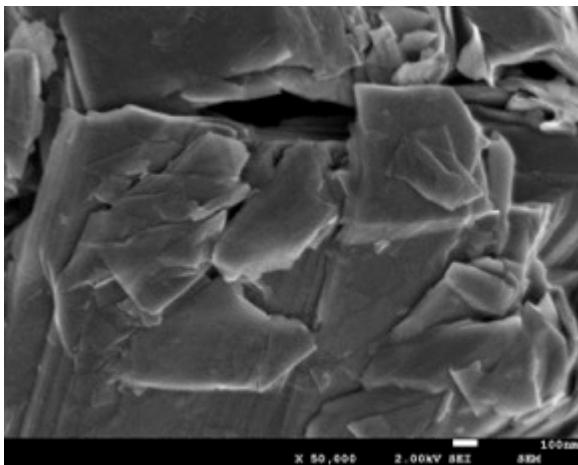
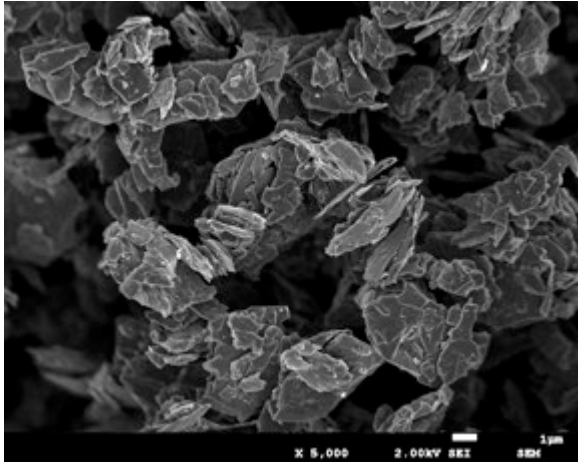
Polymer and Composite market- \$90bn

Sub set-Thermoset resins

- Valued in 2007 at \$7.9bn
- Compound Growth 7-9%
- Valued in 2020- \$19bn
 - Polyester 66% (\$12.5bn)
 - Epoxy 23% (\$4.5bn)
 - Others 11% (\$2bn)
- Polyester- 7.5m tonnes in 2020
- **1% penetration with 2% loading is 1,500 tonnes**

RESIN - INITIAL FINDINGS

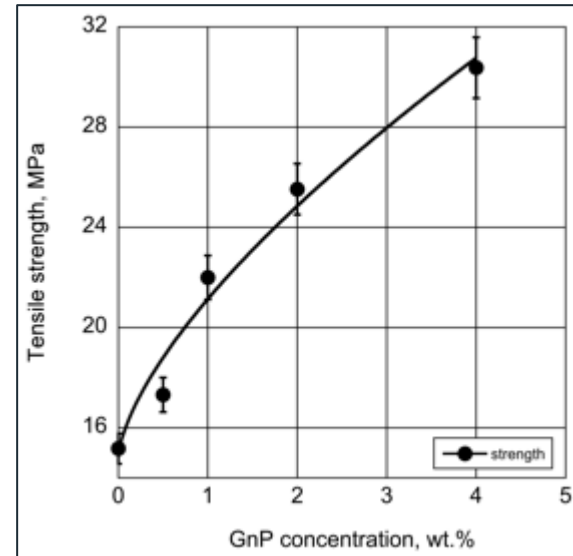
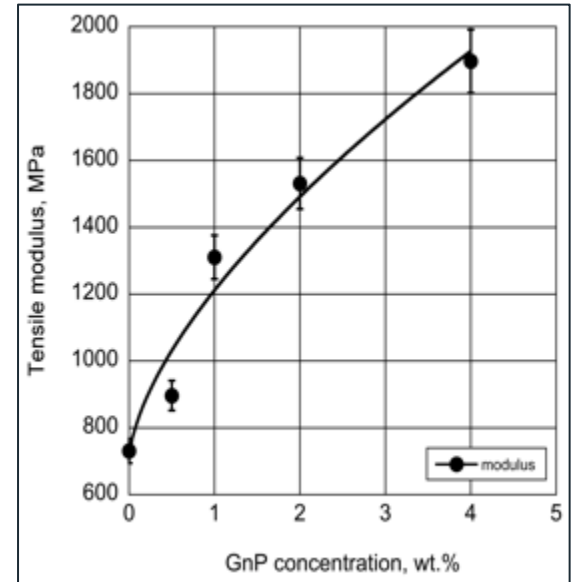




Aerospace Corp

- Accepted for publication in a peer reviewed journal in April 2014
- Haydale GNP cited
- Significant strength improvements in toughened epoxy composites
- The addition of increasing amounts of GNP resulted in significant strength increases and toughness improvements over that of similarly cured, unreinforced material.

Reported in the Journal of Applied Polymer Science 10.1002/APP.40802



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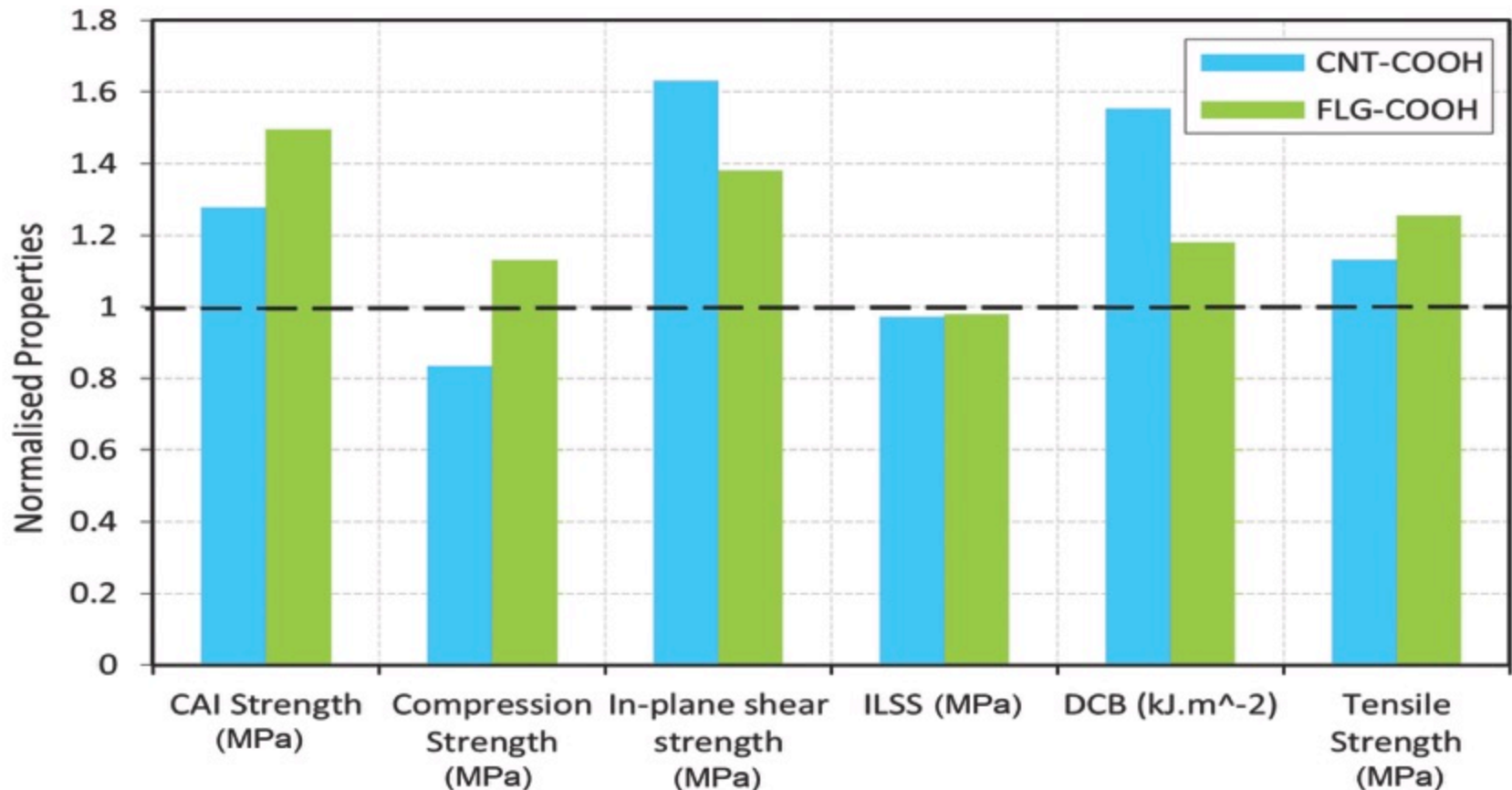
I manufactured 6 loading concentrations for my composites, and I expected to see a degradation or at least a saturation in properties as is usually the case somewhere toward the later half.

I was very surprised to see that your material kept significantly improving both in strength and modulus values. ”

Aerospace Corp

Dr David Hatrick, European Technology Director at Huntsman Advanced Materials said: “We are pleased to be working closely with Haydale on this exciting opportunity. The combination of their expertise in functionalised GNP and our capabilities in epoxy chemistry should create multiple new opportunities to meet the needs of the growing composites market.”

CLEAN SKY- CFRP PROJECT FINDINGS



Applications



Route to Market

- Huntsman
↓
- Aerospace approved pre-preg company (TBA)
↓
- Airbus/GKN Aerospace/BAE Systems

Benefits

- Increased electrical conductivity
- Improved lightning strike
- Eliminate Parasitic Copper
- Increased EMI/EMC resistance
- Improved anti static performance

Market Size

Carbon Fibre Epoxy Composites Aerospace
& Defence (2012)

Global Market* £800 M

Applications



Route to Market

- Huntsman
- Scott Bader



- Marine – Alex Thomson Racing
- Automotive – Briggs Automotive Company
- Rail – Bombardier
- Wind Turbines – TBA
- Pipes & Tanks - TBA

Benefits

- Improved Strength and Stiffness - lighter weight and reduced labour
- Improved Hydrophobicity and Oil/Gas Permeation Resistance
- Increased Toughness and Impact Resistance
- Improved Fatigue Resistance
- Improved Interlaminar Shear - Delamination Resistance



Lighter Weight, Lower Cost Structures
Reduced Labour and Materials

Market Size

Global Market Size* \$20Bn - 2011
\$30Bn - 2017 (7% CAGR)

\$0.5Bn Marine
\$2.8Bn Transport
\$2.4Bn Wind
\$2.6Bn Pipe & Tank
\$8.3Bn Addressable Market

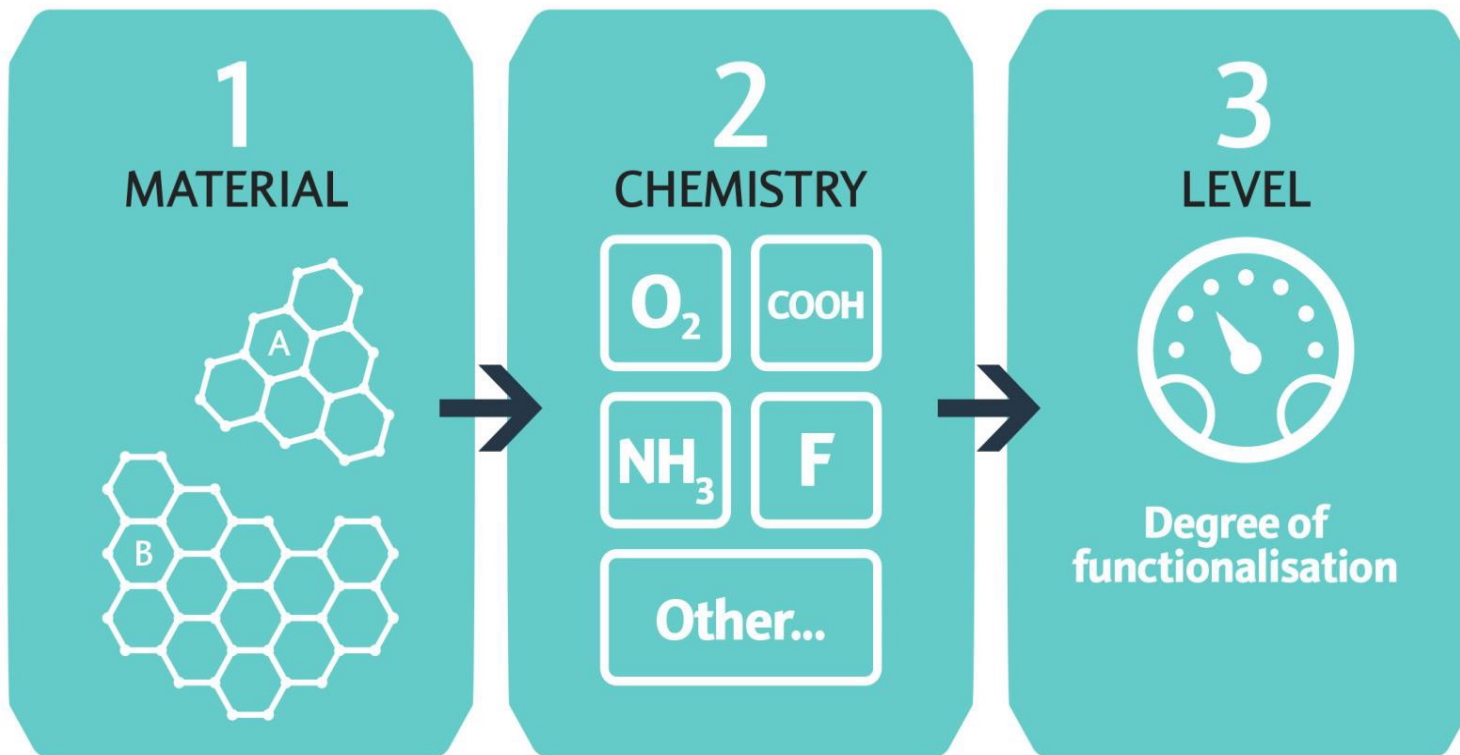
The Industrial Challenge:

- Graphene as a carbon is relatively inert and it needs to be dispersed and bonded to realise its outstanding properties
- Prove it offers improvements
- Production must be repeatable and cost effective
- Environmental impact must be minimal
- Confidence not hype

The Haydale delivery:

- Verified performance of improvement
- Scalable, repeatable, tailored process – controlled functionalisation
- Immediate cost effective quality materials (organic) of “intermediate” products – minimal downstream processing change to incorporate

THE HAYDALE APPROACH

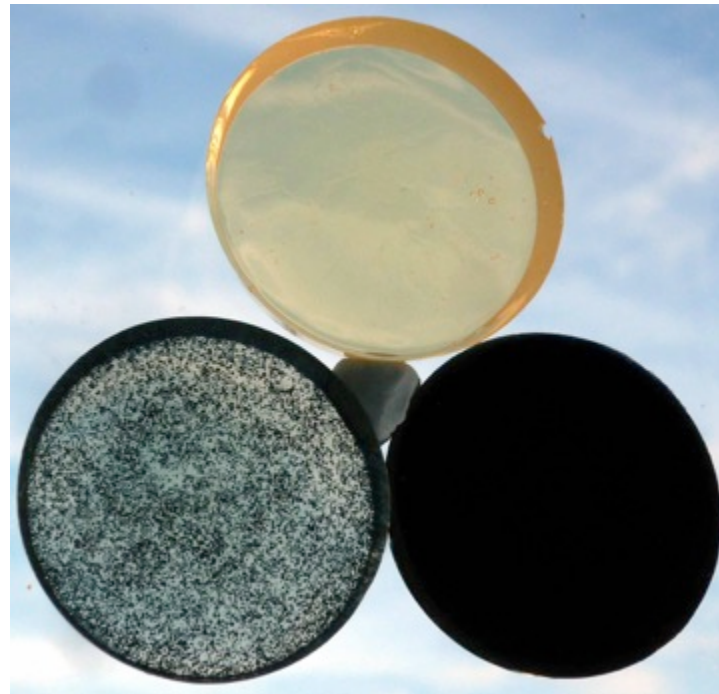


3 Levels of Customisation™

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One material and limited functionalisation will not fit all applications!

Functionalisation and Dispersion



0.5 wt% **NON**
Functionalised CNT in
epoxy resin

Epoxy (no filler)

0.5 wt% Functionalised
HDPlas CNTs in epoxy
resin

Far East

- 10 key accounts established – collaboration opportunities
- Sales and marketing office in Seoul - staffed
- 12 target companies sampled - CNT functionalisation and hybrid
- Conductive inks – sensors

USA

- Established Haydale Technologies Inc,.
- Centre of excellence in process - Grant funding and support in progress
- CNT/GNP functionalisation

UK/Europe

- CPI – Processing – Bridging their technology gap
- NPL – Verification and credibility
- WCPC – Ink and coatings
- HCS – Composites
- AMG – Centre of excellence

Early adopters:

Functional and electronic inks, Coatings, Composites

Why?

- Innovative sectors
- Used other nano materials
- Looking for technical advantage – bridging a technology gap - CPI
- Seeking material USP
- No need to change capital equipment
- Clear route to market - size

Capacity 2014 vs 2015

Scale up confirmed

R&D

New Requirements

- Germany
- Far East
- USA
- UK

Commercial centres of excellence – both HT60 and HT200

CPI – installation November

HT60 – R&D



HT200 –Commercial



- NIH syndrome
- Find the gate keeper
- Not the market leader
- The industry needs scale
- What comes first the order or the capacity
- Using non sustainable, uneconomic graphene in research projects is a massive waste
- The market still needs conditioning
- Hype remains a big issue

Establishing graphene and CNTs as the “must have material”

- Commercial agreements – which is real and deliverable
- The Graphene Industry is not profitable, needs sales orders and credibility
 - Inks/Coatings/sensors
 - Composites
- Materials will often need functionalising
- Centres of excellence being established world wide
- Commercial and Government inbound investment remains crucial - underpinning R&D for future products

BUT- taking from the Lab to full scale production is not easy and end product often differs from the lab results

Price/performance conundrum needs to be understood

The new wonder material

- **The science/materials/markets are complex**
- **We need standardisation – but cant wait**
- **Haydale is committed to growing the market**

HOW?

- **By getting the materials fit for purpose**
- **Delivering consistent quality in volume**
- **At an affordable price**
- **Into targeted markets- Composites/Inks**