



GRAPHOSITE PROJECT

A GRAPHENE SENSOR FOR DEFECT DETECTION AND PREDICTIVE
MAINTENANCE IN COMPOSITE MATERIALS

PROJECT PARTNERS AND SERVICES BOOKLET

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Innovate UK This project is supported by Innovate UK

GRAPHOSITE Project Ref. 104266

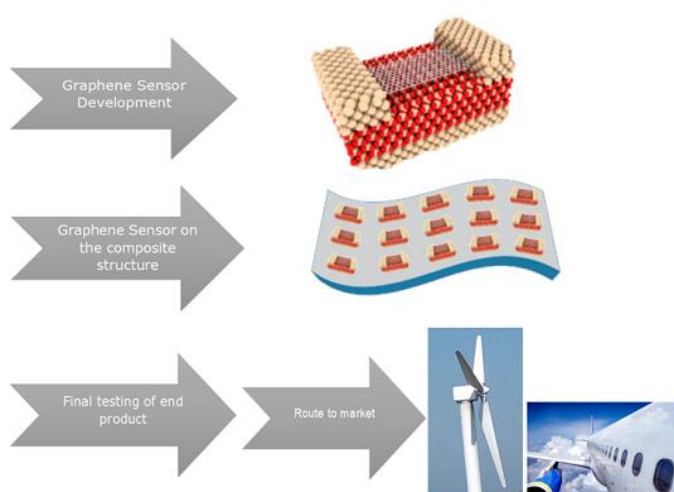
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INTRODUCTION

The GRAPHOSITE is 30-month project funded by Innovate UK (reference 104266) which started in August 2018, it will run until January 2021.

The most common defect during the manufacturing process of composite materials is porosity; the presence of small voids in the matrix. Porosity levels can be critical as they affect mechanical performance causing issues such as inter-laminar shear stress. In-service damage is mainly caused by impact, resulting in internal delamination which is barely visible, or puncture to the material's surface which is a frequent occurrence. Sandwich structures can also suffer from delamination in the skins when impacted as well as matrix cracking. Core crushing occurs where impact energy is absorbed by the core, which distorts and folds. It often then returns to its original shape but will have greatly reduced compressive strength as a result.



GRAPHOSITE offers a technological solution that addresses a significant challenge to composite materials - defect detection. It aims to apply graphene to a customised substrate to achieve enhanced defect sensing and predictive maintenance with increased sensitivity. The sensor will be embedded with the composite during manufacturing and will have high flexibility properties. A unique feature of the novel technology is that graphene will serve as the sensing element and act as the gate through which the electric current passes. Being an embedded part of the composite at manufacture, condition monitoring will therefore be continuous and in real-time.

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TWI LTD.

WHO WE ARE

TWI is one of the world's foremost independent research and technology organisations, with expertise in materials joining and engineering processes as applied in industry. TWI specialises in innovation, knowledge transfer and solving problems across all aspects of manufacturing, fabrication and whole-life integrity management. Established in Cambridge, UK in 1946, the organisation has gained a first-class reputation for service through its teams of respected consultants, scientists, engineers and support staff. With around 800 employees, it works with over 1800 Industrial Member companies in over 70 countries. TWI currently operates from 54,000 square metres (581,000 square feet) of manufacturing, testing and training space; five UK and 13 overseas facilities serve both its Industrial Membership and its training and examination needs. A successful international Training and Examinations programme sees around 25,000 students trained each year in welding and inspection technologies.



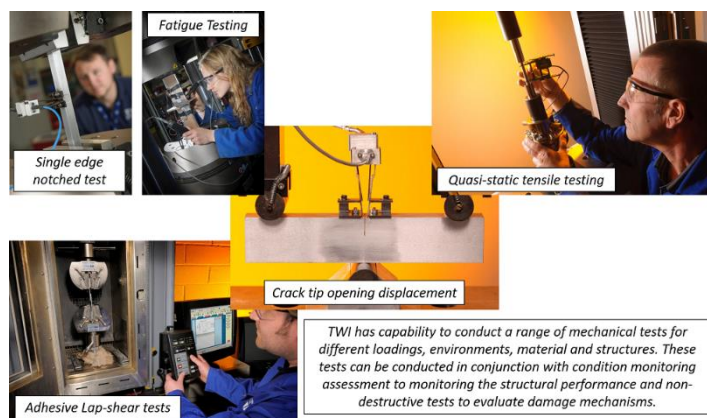
TWI UK Offices



TWI Global Presence

OUR PRODUCTS AND SERVICES

TWI carries out confidential research contracts for Industrial Members and has an extensive programme of core research and collaborative projects. TWI's experts can offer consultancy on all aspects of fabrication and performance of structures, including expert witness and arbitration services. The NDE Group at TWI conducts development and research in a number of different NDE technology areas including automated inspection, condition monitoring and bespoke inspection innovations for specific challenges. The NDE group operates across a wide range of industrial sectors include aerospace, renewable energy, nuclear, defence, and oil and gas. The Monitoring and Inspection Research (MIR) section within the NDE group provides expertise in the





TWI has expertise in a wide range of non-destructive evaluation methods and techniques. This includes both non-destructive testing and condition monitoring solutions. Techniques include; Ultrasonics, Radiography, Acoustic Emission and Vibration. TWI develops novel techniques to solve industrially led challenges.

development of new and innovative technologies driven by industry demand. Through a series of collaborative projects with selected partners, MIR is working to develop the next generation of monitoring and inspection solutions through multidisciplinary strategies. In regards to condition and structural monitoring, MIR offers expert advice in condition and structural monitoring strategies for unique

problems and harsh environments, signal processing, algorithm development, embedded sensing, technology and procedure qualification. MIR particularly focuses on acoustic emission, vibration, ultrasonics and strain measurement.

ROLE IN THE PROJECT

TWI's role in the Graphosite project is to conduct sensor validation in a laboratory environment. TWI has much expertise in qualifying technology, in particular, technologies that are under development. This involves the preparation of a testing plan to demonstrate the validity of the data produced from the prototype sensor. This requires trials to be designed where a direct comparison against a known sensor can be conducted. This is being conducted on carbon-fibre and glass-fibre coupons subjected to mechanical loading. TWI is also responsible for analysing the data to establish the repeatability of the results, accuracy and precision, and the robustness of the sensor. TWI also contributes and coordinates the technical evaluations between project partners, ensuring the different fields of expertise are synergized in an effective and efficient manner towards achieving the collective project goals and objectives.



In collaboration with the other project partners, TWI reviews the project finances and is responsible for reporting them to Innovate UK with justification. With the other project partners, TWI co-ordinates the project and technical delivery to Innovate UK. TWI is committed to working with the Graphosite consortium to deliver a novel sensing technology and seek exploitation opportunities.

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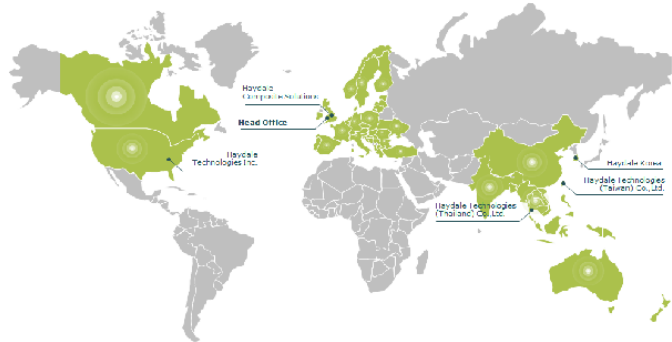


www.twi-global.com

HAYDALE COMPOSITE SOLUTIONS LTD.

WHO WE ARE

Haydale is a global technology solutions company passionate about creating the next generation of advanced materials by bringing together cutting-edge technology with engineering know-how to enhance the performance of products and materials thus delivering business value for our customers. We:



- Use tailored advanced materials to enhance the quality and performance of our customers' products
- Develop nanomaterial enhanced resins for the prepreg carbon fibre market to deliver enhanced electrical, thermal or mechanical performance to the aerospace, automotive and other hi-tech industries
- Offer nanomaterial enhanced polymers for additive manufacturing that allow better products to be made faster
- Formulate proprietary nanomaterial-based inks and coatings for the print and sensor markets, including regulatory approved ink for biomedical sensors
- Manufacture unique, proprietary silicon carbide fibres and whiskers that strengthen ceramics and enable highly scratch and wear resistant coatings for applications as diverse as cookware coatings, cutting tools that make jet engine turbine blades and corrosion protection for oil and gas pipelines

We are at the start of the fourth industrial revolution and we are helping companies seize new opportunities.



OUR PRODUCTS AND SERVICES

Inks & Coatings

Our unique functional inks provide performance enhancements and cost reductions. These conductive & piezoresistive products offer a unique blend of nanomaterial enhanced and silver inks, which offer unique properties into the coating and paint markets for anti-abrasion, wear and corrosion.

Composites

Haydale continues to develop its range of masterbatch, prepreg and resins for use in composite manufacturing, offering enhanced mechanical, electrical and thermal properties. We specialise in the design, testing, certification and commercialisation of composite structures.

Ceramics

Haydale's custom Silicon Carbide fibre materials have a wide range of applicability, from ceramics, to polymers, to metal matrix composites. Our products impart toughness and durability and survive in the most challenging environments.

Elastomers

We compound nanomaterials into a range of elastomers to support customers using nanomaterials in elastomeric products for a range of property improvements, such as thermal conductivity, electrical conductivity and increased mechanical performance.

ROLE IN THE PROJECT

Haydales' role in GRAPHOSITE is to act as the end-user; defining the end-user requirements including:

- Potential exploitation routes, applications such as Aerospace and Wind Energy
- Materials specifications – resin type, fibre type
- Manufacturing processes – hand lay-up, resin infusion, autoclave
- Prototype development including integration of sensor(s) into/onto composite structure
- Mechanical testing and performance evaluation of sensors under typical load scenarios and impacts



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www.haydale.com

BRUNEL COMPOSITES CENTRE

WHO WE ARE

Brunel University London has been highly successful in creating an industrial innovation research resource, named **Brunel Composites Centre (BCC)**, which sits between the knowledge base and industry, supporting partners in industry to transfer academic research into industrial application. BCC is a shared research and technology capability specialising in novel composites processing and joining technologies, applied to industrial environments. It undertakes joint research programmes and aims to develop the next generation of technologies and engineers.

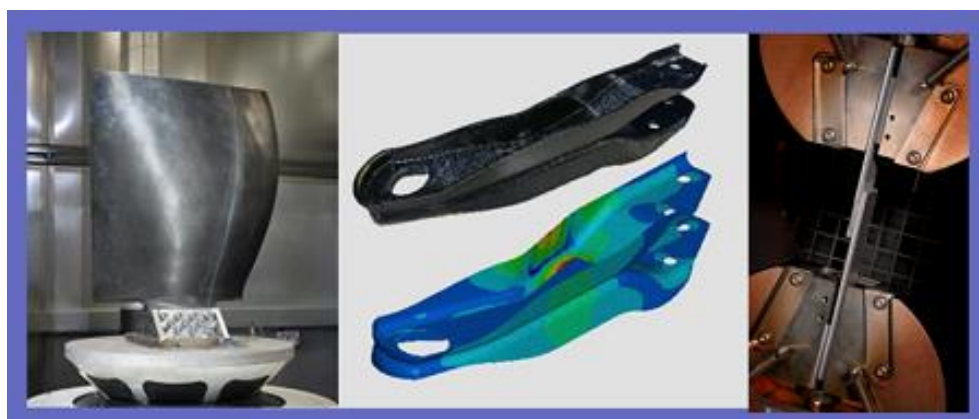
Objectives:

- Create solutions for better processing and joining of composites
- De-risk innovation in composites for quick industrial adoption
- Establish a world leading reputation in composites and joining



OUR PRODUCTS AND SERVICES

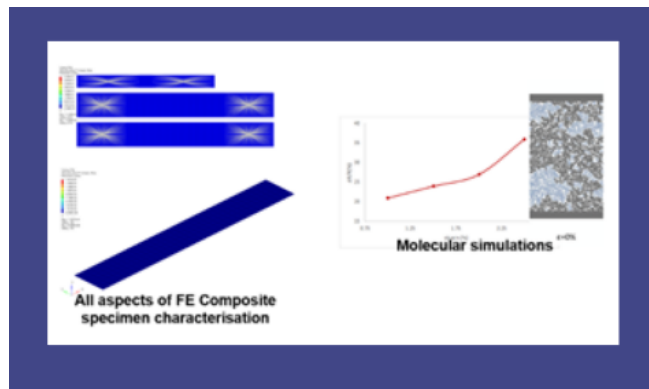
- Multiscale FEA capabilities
- Composites joining without mechanical fastening
- Developing advanced out-of-autoclave tooling
- Microwave heating in composite production
- Novel processing of composites
- Composites-metal joints
- Coatings for composites
- Adhesive bonding



ROLE IN THE PROJECT



BCC specialises in multi-scale modelling of composite structures. For Graphosite, the main role of BCC is to carry out molecular simulation of different substrates, to simulate the functionality of the chosen sensor by modelling the Sensor, the dielectric, the material of the source and drain and to simulate the sensor response to different strains and compare it with experimental results. BCC also leads the task for defect detection on composite structures, physical tests and supports in all the characterisation tests in order to validate the sensor.



MAIN CONTACT:

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www.linkedin.com/company/brunel-composites-centre

DZP TECHNOLOGIES LTD

WHO WE ARE

DZP Technologies is a leading developer of specialty materials, formulations, and printing technologies for emerging industries. Founded in 2008, we have been working closely with our customers to create innovative materials for a range of markets, from consumer electronics and wearables, to 3D-printing and renewable energy.

Our scientific expertise and talented team make it possible to fast-track scientific discoveries from lab to market, taking on the toughest technical challenges and helping our customers develop innovative, sustainable products which offer a true differentiator in competitive markets.

Our business strategy is based on partnerships and building trust. Whether we work with a start-up company or a global multinational, our customers enjoy access to our leading edge scientific expertise and innovative products, with fast delivery times and while protecting and respecting their intellectual property. Our strong customer focus combined with our unique products and service offering have gained us clients globally, from the UK, France and Germany, to the US, Singapore and South Korea.

We specialise in aqueous inks and pastes which are both user- and environmentally-friendly. This is fully aligned with industry trends to minimise the environmental impact, while reducing costs and improving performance of new technology.

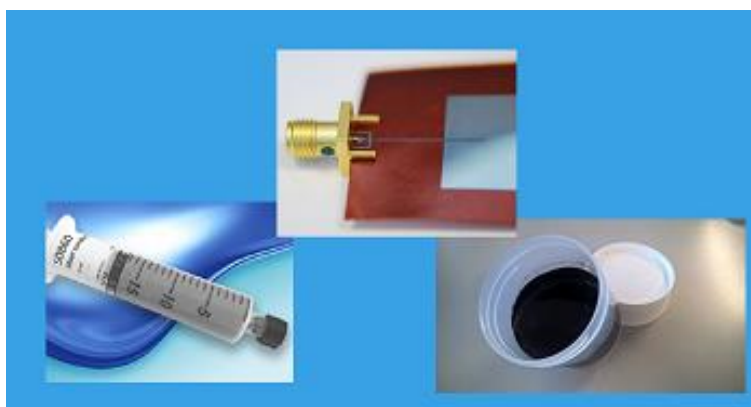


OUR PRODUCTS AND SERVICES

Silver Conductive Inks

Our products make use of the latest advances in materials science and technology to provide user-friendly, aqueous conductive inks and pastes which match the performance of the conventional solvent inks. Our silver conductive technology provides the following key benefits:

- Low temperature curing (25 – 120 °C) and suitable for printing on heat-sensitive polymers, composites, paper and textiles
- Wide temperature operating range (-65 – 220 °C) and excellent mechanical and environmental stability once cured.

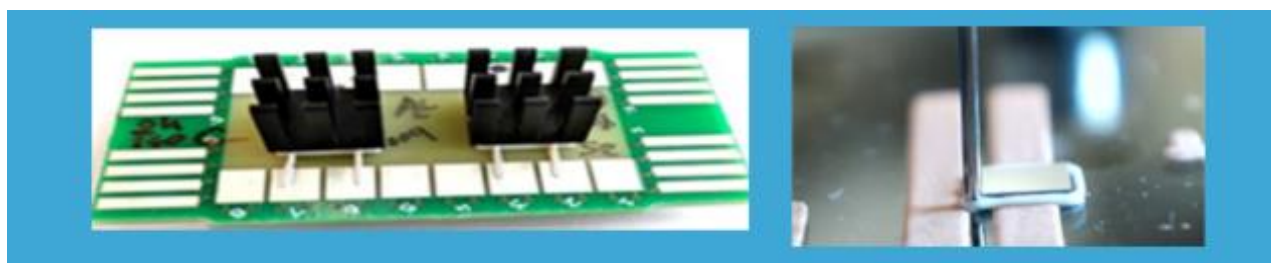


Graphene Inks and Pastes

With a focus on commercially viable technology development, we work in the chasm that often exists between the academic research centres and companies seeking to develop graphene products that fill a market need.

Our portfolio of more than 50 bespoke graphene formulations means that we are likely to already have the best technical solution for a particular application on hand. With no tie to a specific graphene raw material, our primary focus is on the best solution for a specific product, and not the 'take-it-or-leave-it' approach often found with large commercial ink manufacturers which offer off-the-shelf products. We have experience in the following graphene technologies:

- Conductive graphene inks and thick pastes
- Aqueous graphene dispersions
- Graphene energy storage (supercapacitors and batteries)
- Graphene sensors



Our services

- Formulation and development of bespoke inks, pastes and processes according to customer specifications
- Prototyping and small volume production of printed devices
- Technical consultancy, contract R&D and contract product development



Products

Off the shelf inks and adhesives



Service

Custom ink development



Contract work

Contract R&D, prototyping and small volume manufacture

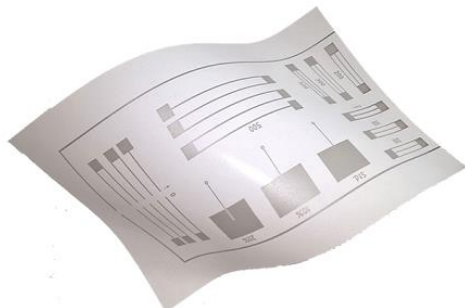


R&D

Longer term research (e.g. battery electrodes, Innovate UK grants)

ROLE IN THE PROJECT

DZP is developing the graphene materials and sensor assembly processes which are required for producing the GRAPHOSITE sensor.



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DZP Technologies

Delivering printed electronics innovation

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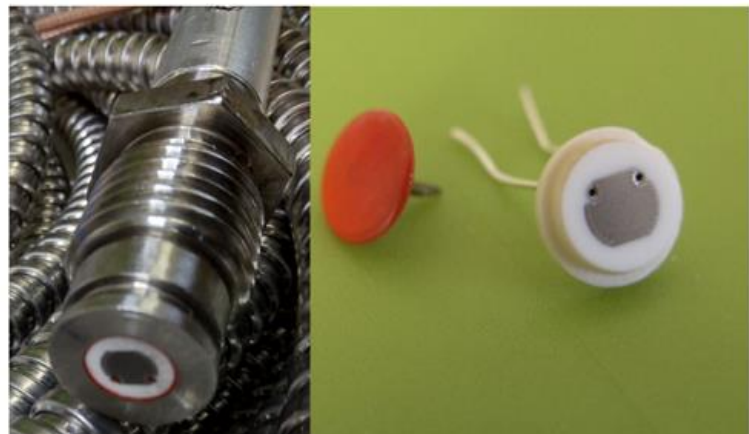
ADVISE DETA

WHO WE ARE

ADVISE-DETA is a new company specialising in the design, construction and installation of in-process dielectric sensors and on-line monitoring and quality assurance systems for composites manufacturing processes. The knowledge and the IP rights of the relevant technology have been transferred to ADVISE-DETA from the Greek company ADVISE, which has a track record of developing quality control systems for advanced manufacturing processes as a result of research projects and bilateral collaborations with leading European and UK composite manufacturers.

ADVISE-DETA has established its 'process control and QA technology' laboratory in Bedford to support the installations of sensors, monitoring and quality control systems at leading composite manufacturing facilities in UK. The company has instrumented autoclaves, RTM moulds and pultrusion lines with dielectric sensors, advanced material state monitoring systems and on-line ultrasonic NDI testing equipment.

The core technology development within ADVISE-DETA lies with interdigital sensors, which have been applied to several fields, among other to cure monitoring, inspection and diagnostics of membranes purifying gases and nanomaterials dispersion in liquids. Around the sensing elements, the company has developed measurement electronics, software tools for data acquisition, modelling, simulation, optimisation and process control.



Dielectric sensor for cure process monitoring & Dielectric sensing elements

OUR PRODUCTS AND SERVICES

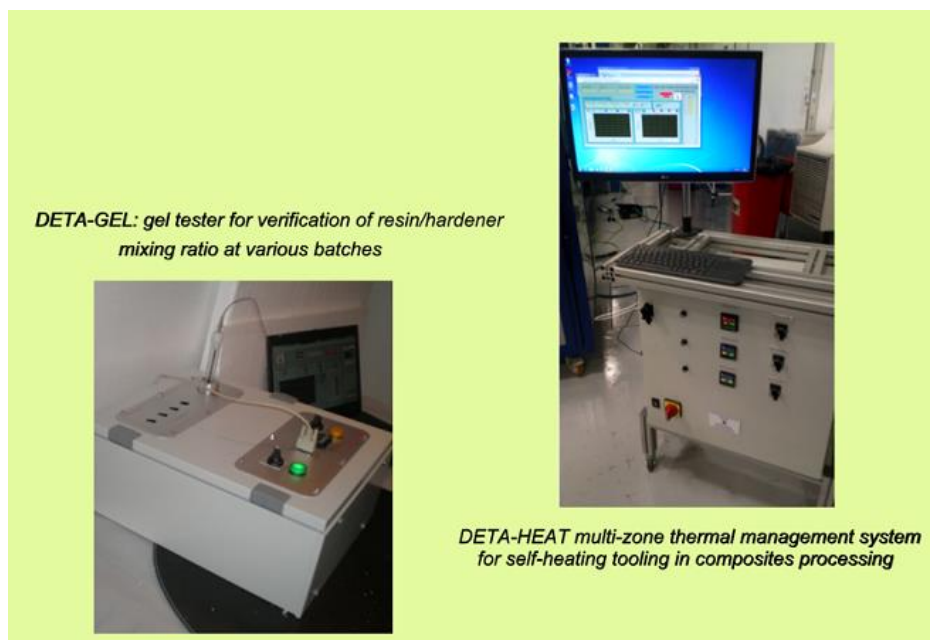
The activities of **ADVISE-DETA** are focusing on the application of measurements of the dielectric properties of the reacting resin to the process monitoring, optimisation and control of composite materials manufacturing. The company has developed all the components of a complete Cure Performance Monitoring System, DETA SCOPE, linked to highly durable dielectric sensors fit for batch and continuous processing of composites. The



DETA SCOPE Cure Performance Monitoring tool showing the traces of degree of cure during a 4-sensor process

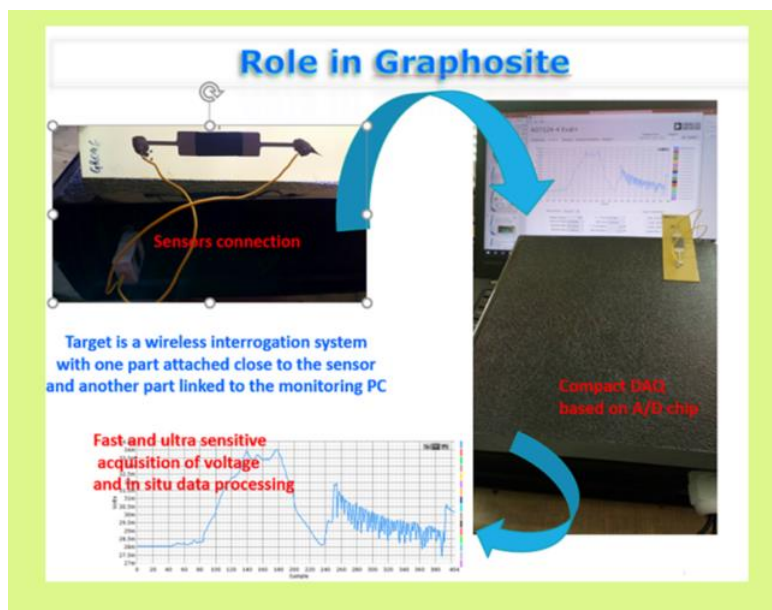
readings from the sensors are translated in real-time to actual material properties (i.e. viscosity and degree of cure). The operation of the system can improve the efficiency of production by determining optimal process conditions, which are inherently affected by the type of material and the geometry of structure.

Other products of ADVISE-DETA include DETA GEL (quality assurance system through gel detection and die profiling for pultrusion industries), DETA LEARN (cure profile optimisation software suite for composites manufacturing), DETA HEAT (multi-zone heating systems for self-heated tools) and PUL-NDI (on-line defect detection for composite profiles).



ROLE IN THE PROJECT

ADVISE-DETA is involved in the development of the data acquisition system for graphene sensors and the facilitation of on-line measurement of strain and health monitoring of structures where the graphene sensor is attached.



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ADVISE



ADVISE-DETA

www.advise-deta.com

CAMBRIDGE NANOMATERIALS TECHNOLOGY LTD.

WHO WE ARE

Cambridge Nanomaterials Technology Ltd (CNT Ltd) is an innovation management and nanotechnology consulting company based in Cambridge, UK.

The CNT Ltd helps companies, academic and government institutions to develop world-class innovative solutions for nanomaterials related R&D and IPR strategy, partnership, products, technologies, funding and markets. CNT Ltd is specialised in carbon nanomaterials R&D consulting and collaborative R&D project management, including exploitation and dissemination management, consortium and supply chain building. CNT has done a number of patent landscaping and market research analysis studies regarding production and use of various nanomaterials helping to link inventors and technology developers with end-users and investors.

The CNT Ltd is a leader of two private consortiums: **NANO-CARBON ENHANCED MATERIALS (NCEM)** and the **ADVANCED MATERIALS FOR ADDITIVE MANUFACTURING (AMAM)** with members coming from leading multinational companies and research institutions. Through both private consortiums NCEM and AMAM, as well as private and public contracts, CNT Ltd has established strong relations to the aerospace, automotive, construction, electronics, materials development, biomedical and chemical industry.

In March 2019 CNT Ltd opened a sister company CNT INNOVATION based in Brussels, Belgium, with the aim to support and complement their work, especially in European related activities.



NCEM-AMAM

OUR PRODUCTS AND SERVICES

The summary of our services is:

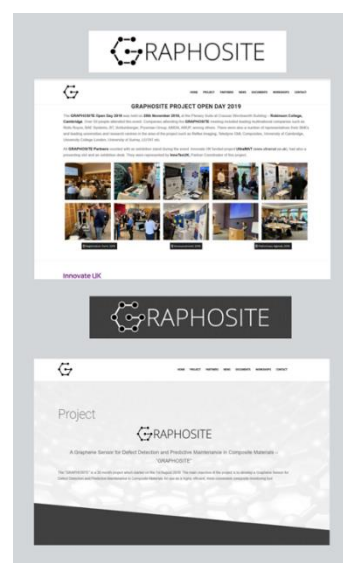


- Consulting and an expert advice related to nanomaterials regarding their production, composites, applications, key players, funding and market. Experts with more than 20 years of experience in commercialisation of carbon nanomaterials (graphene, carbon nanotubes, carbon nanofibres, etc.).
- Innovation management and technology transfer support related to R&D of novel nanomaterials & composites.
- Advice and support related to development of Intellectual Property (IP) Strategy – patent landscaping reports, due diligence, invention and protection.
- Market Research and Strategy - market research reports, consulting and advice about innovation, new product strategy and development, proof-of-concept, market and funding.
- Organisation of nanomaterials and nanotechnology application related conferences, workshops and customised training, seminars and support multinational companies and research institutions.
- Management in collaborative R&D projects, such as EU Horizon 2020 projects: EPPN project (www.eppn.eu); n-TRACK (www.n-track.eu); Oyster (www.oyster-project.eu); M3DLoC (www.m3dloc.eu); Genesis (www.genesis-h2020.eu); and Repair3D (www.repair3d.eu); as well as Innovate UK projects: UltraMAT (www.ultrammat.co.uk) and GRAPHOSITE (www.graphosite.co.uk). Consortium set-up, grant proposal writing support; exploitation and dissemination management; liaising with EU officials.



ROLE IN THE PROJECT

Cambridge Nanomaterials Technology Ltd. is leading the exploitation and dissemination activities of the GRAPHOSITE project. CNT is in charge of the project website (www.graphosite.co.uk), leaflets, workshops, Intellectual Property (IP) strategy, and preparation of patent landscaping reports. We are also involved in market research, business development and exploitation strategy of the project.



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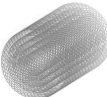


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