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Graphene & Nanofillers for Composites Workshop

Speaker Profiles

Polymer Composite Additive Manufacturing to Simultaneously Build Hierarchical Materials and Net-shape Structures
Dr Ben Farmer, EADS Innovation Works

Biography: Ben Farmer is a Senior Research Engineer at EADS Innovation Works and leader of the transnational and multi-business unit 'Shared Research Project' on Additive Manufacturing. He also leads a number of EADS upstream research activities focused on nanocomposites, multifunctional materials and additive manufacturing, as well as projects for external customers and business development activities. Ben joined EADS via Airbus in 2006 where he was responsible for generic composite technologies research, leading a multidisciplinary transnational team covering new materials & processes, design, stress, structure integration and manufacturing. At Airbus and since moving to EADS Innovation Works in 2010 he has filed more than ten patent applications in the areas of nanocomposites and additive manufacturing. Previously to Airbus, he managed an EU FP6 Innovative Actions project at the University of Bath to foster technological innovation in small and medium aerospace businesses in the South West of England, and prior to that was a Composites Engineer at Cobham Advanced Composites Ltd. Ben holds a first class honours degree in Materials Science and Engineering from the University of Bath and a PhD in carbon nanotube fabrication from the University of Cambridge. He is a member of the Executive Committee of the British Composites Society, an Honorary Fellow of the University of Exeter and an MBA candidate at the University of Bath. Ben is married with one son and lives in Bristol.

Abstract: Developments in metallic materials for additive manufacturing (AM), such as EADS Scalmalloy®, have shown opportunity to tailor specific material concepts to good effect for improved properties. Developments in polymer composites for AM have, however, significantly lagged behind. In parallel, developments in continuous fibre polymer composite technologies are exploiting nano-materials by means of nano-augmented, nano-engineered and nano-enabled approaches. The nano-enabled approach provides an opportunity to make joint developments with AM to realise new materials which can be processed in net-shape and with a high degree of control over morphology. Strategies for net-shape layer-by-layer AM of composite materials are described and develop progress presented.

Large Volume, Bottom Up Synthesis of High Purity Graphene Nonplatelets for Composite Application
Dr Karl Coleman, Chief Technical Director, Applied Graphene Materials

Biography: Karl is a Professor of Inorganic Chemistry at Durham University, having previously been in the chemistry departments at the University of Oxford and the Université de Strasbourg. Karl achieved a PhD in Chemistry at the University of Leicester in 1996 and is a Chartered Chemist, Chartered Scientist and fellow of the Royal Society of Chemistry. His work since 2000 has focused on nanoscience and nanotechnology, particularly the chemistry of carbon nanotubes and graphene. He has been funded by the Engineering and Physical Sciences Research Council and the Royal Society and he has authored / co-authored over 75 publications in peer

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reviewed journals which have accumulated over 2,500 citations. His work has been recognised with numerous awards, including the international Royal Society of Chemistry Entrepreneur of the Year Award 2011 for his development of intellectual property around the production of graphene, and the Times Higher Education Research and Innovation Award 2012. He is the secretary of the Chemical Nanosciences and Nanotechnology subject group of the Royal Society of Chemistry. Karl established Applied Graphene Materials in 2010.

Abstract: Applied Graphene Materials – a spin-out from Durham University- has developed a novel,bottom-up synthesis method for the manufacture of high specification graphene in large volumes. The AGM process delivers highly dispersible,substrate-free graphene nanoplatelets that can be readily incorporated in a variety of composites and solutions to enhance mechanical,thermal,electrical, and gas barrier properties. AGM has established its first large scale producion facility designed for producing tonnes of graphene per year and is currently engaging customers across the globe to develop application specific, graphene enhanced materials. AGM offers graphene products,together with dispersal and product integration expertise.

Melt Processing Composites of Polymers and Carbon based Nanoparticles

Prof Tony McNally, Chair in Nanocomposites & Director – International Institute for Nanocomposites Manufacturing, WMG, University of Warwick

Biography: Tony McNally is Professor and Chair of Nanocomposites at the Warwick Manufacturing Group (WMG), University of Warwick, and is the first Director of the International Institute for Nanocomposites Manufacturing (IINM) at the University of Warwick. Prior to this, he held a number of positions in academia and R&D in the automotive and medical device industries. His current research interests are focused on; melt processing of polymer nanocomposites; functionalisation of nanoparticles, including the use of ionic liquids to modify layered silicates and non-covalent functionalisation of carbon nanotubes; polymer nanocomposite drug delivery; composites of polymers/metals with carbon nanotubes, graphene/GO and nanowires and the use of electric and magnetic fields, solid-state and melt processing techniques to orientate nanoparticles in polymers.

Abstract: Despite more than two decades of intense research effort extensive commercial exploitation of composites of polymers and nanoparticles has not been fully realised. Notwithstanding the limitations of the synthetic routes to the production of nanoparticles without defects, devoid of impurities and in large volumes, two grand challenges remain. The first is associated with the dispersion and distribution of nanoparticles in polymer melts using conventional polymer processing technologies, the second understanding the structure, morphology and critically the properties of the interfacial region between polymer and nanoparticle. This presentation will provide an overview of melt processing of composites and blends of polymers and carbon based nanoparticles, with a focus on carbon nanotubes, highlighting the factors which must be addressed to prepare a useful composite material.

Processing & Properties of Graphene Composites

Dr Cristina Vallés, University of Manchester - National Graphene Institute

Biography: Cristina Vallés obtained her B.S. degree in Physical Chemistry and Ph.D. degree in Materials Science in 2006 from the University of Zaragoza (Spain). She worked as a Postdoctoral Researcher at the Centre de Recherche Paul Pascal

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(CRPP), CNRS, University of Bordeaux I, France (2007–2009), and at the Instituto de Carboquimica, CSIC, Zaragoza, Spain (2009–2011), where she focused her research on the study of the chemistry of graphene and graphene oxide. Currently, Vallés is working as a Post Doctoral Research Associate at the School of Materials, University of Manchester, UK (from 2011). The focus of her current investigation is the production of graphene-based composites, processing and evaluation of the mechanical and thermal properties.

Abstract: Graphene has attracted significant interest since its first isolation at the University of Manchester in 2004 due to its extraordinary physical properties which make it ideal for a wide range of applications. Due to its impressive electronic properties, the incorporation of graphene in sensors and semiconductor devices seems very promising. In addition the mechanical, thermal, electrical and gas barrier properties of graphene make it an ideal candidate to be used as filler for polymer matrices in composites, membranes, barriers and coatings. Graphene has also been found to be promising in life sciences related applications, such as sensors, drug delivery, tissue engineering or nanotoxicology. The University of Manchester is widely involved in projects related to all these applications, as well as in the study of the fundamental physical properties of graphene and development of processing routes and characterization standards related to these materials.

In particular, graphene/polymer nanocomposites are being the focus of many investigations due to their exceptional thermal, mechanical and electrical properties. The development of methods for the mass production of graphene and the processing of homogeneously distributed graphene into solvents/polymers is a priority for these large-scale applications. The most preferable route for producing bulk quantities of graphene is the chemical conversion of graphite to graphite oxide via the Hummers' method. Recently graphene oxide (GO) prepared using the Hummers' method has been shown to be composed of functionalized graphene sheets decorated by strongly-bound oxidative debris acting as a surfactant that stabilizes aqueous GO suspensions. These physi-absorbed aromatic acids can be removed by a simple NaOH(aq) wash to give base-washed GO (bwGO) reducing the oxygen content from 33% to < 20%, turning the hydrophilic nature of GO into hydrophobic, and improving the conductivity of films made from the material by 5 orders of magnitude.

Herein, we compare as-made and base-washed graphene oxide materials as reinforcing fillers in PMMA to establish the relative roles of the interface and GO modulus, and determine whether it is better to use as-made GO or base-washed, clean GO in nanocomposites to reinforce the polymer.

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Up-Scaled Production of Graphene Reinforced Thermosetting Polymers for Composite Applications

Dr Matthew Thornton, Project Manager, NetComposites

Biography: He has a BSc (Hons) in Chemistry with Chemical Engineering and a PhD in Materials Science and Engineering. Following his studies Matthew spent 18 months as a KTP Associate at the University of Reading, researching novel materials for the removal of mercury from crematoria flue gases, before spending 7 years at the Institute of Materials, Minerals and Mining as both a Materials Advisor and the Polymer Sector Leader for the Materials Knowledge Transfer Network. He joined NetComposites in August 2013.

Abstract: This presentation will introduce the EU FP7 funded Polygraph project and will look at techniques to develop new routes for the manufacture of industrial-scale quantities of graphene-reinforced thermosetting polymers; starting from a relatively

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inexpensive expanded graphite starting material.

The presentation will discuss new chemical and mechano-chemical methods to exfoliate the expanded graphite and produce graphene, as well as the techniques necessary to disperse the graphene into low-viscosity thermosetting polymers in a uniform, consistent and scalable basis and to enable the in-situ exfoliation of the expanded graphite and dispersion of the resulting graphene in a single operation for the production of fibre-reinforced composites, adhesives and coatings.

Key target industry sectors for this work include the aerospace and automotive sectors.

Plasma Functionalised Nanomaterials for Multi-scalar Composites

Martin Williams, Technical Manager, Haydale Ltd

Biography: Martin Williams has been developing plasma processes for functionalising bulk quantities of powders for 7 years and has been focusing specifically on nano-carbons for 4. Martin now develops the Haydale plasma technique to deliver bespoke functionalisation tailored to specific applications. Quantifying the surface functionalisation through both particle analysis and consequential component analysis and then marrying these two approaches to characterisation is an on-going challenge. He is involved in a number of projects to exploring nanomaterials in thermoplastics, fibre reinforced composites, nanomaterial standardisation, sensor technologies and health and safety.

Abstract: Reports on the performance of composites which include nanomaterial fillers varies widely from incredible improvements to reductions in performance. This presentation will explore some of the reasons why there is such disparity between reported results and what plasma functionalisation can do to improve performance. Some recent results on nano-filled composites will also be reported which show improvements in fibre reinforced materials, but little or no change to resin performance.

Exploitation Opportunities in Aerospace and Defence

Dr Amir Rezai, Advanced Technology Centre, BAE Systems

Biography: Dr Amir Rezai is a principal scientist and project manager at BAE Systems, Advanced Technology Centre (ATC). ATC is the corporate research centre for the wider company serving the diverse technological and R&D needs of the BAE Systems subsidiary business units. Amir joined ATC's Materials Sciences department in 1994 following a 3-year post doctorate fellowship at University of Surrey, studying micromechanics of failure in composites. He specialises in polymer composites and lightweight structures and his research interests include multi-scale damage tolerance, impact survivability, multi-functional materials, low cost manufacture and environmental resistance.

Abstract: Advanced aerospace and defence application increasingly demand mass efficient multi-functional structures to help maintain competitive advantage and meet market and environmental drivers. Consequently, conventional fibre reinforced composites are increasingly materials of choice for design of air, land and marine vehicle platform. A wide spectrum of focused composites R&D is addressing material deficiencies such as damage tolerance and requirements for lower cost manufacture and multi-functionality. Nanocomposites are seen as an enabling technology to further augment the performance of composites imparting improved structural, protective and functional properties. The presentation will draw on potential applications across the domain highlighting their benefits and challenges.

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Frequency Dependent Conductivity & Permittivity Properties of Composites

Prof Chris Bowen, University of Bath

Biography: Christopher Rhys Bowen has a BSc degree in Materials Science from the University of Bath (1986-1990) and a DPhil in Ceramics from the University of Oxford (1990-1993). Post-doctoral work has been undertaken at Tecnische Universität Harburg-Hamburg and University of Leeds (1994-1996). He was Senior Scientist at the Defence Evaluation and Research Agency (DERA) from 1996-1998. He joined the University of Bath as a Lecturer in 1998 and is now Professor of Materials and ERC Advanced Investigator, ERC Grant Agreement no. 320963 on Novel Energy Materials, Engineering Science and Integrated Systems (NEMESIS). Research areas include energy harvesting, piezoelectric materials and functional ceramic/composites.

Abstract: Networks of randomly positioned resistors and capacitors can be used to simulate the microstructures of heterogeneous materials. The networks exhibit fractional power law frequency dependences of permittivity and conductivity; as seen for many materials. Two observations are (i) power law dependencies are observed when the ac conductivities of the resistors and capacitors are similar and (ii) the network response was related to the resistor and capacitor values by a simple logarithmic mixing rule. The logarithmic approach is used to model the electrical characteristics of two-phase conductor-insulator mixtures including ceramic composites and carbon-nanotube and graphene oxide polymer composites.

NanoDiamond Fillers – Big Changes from Small Particles

Gavin Farmer, Director, Carbodeon

Biography: Gavin established Fairland Technology in 2012, to support small and medium companies with exciting technology. He is focussed on matching company offerings to market requirements to “create value from technology”. Gavin has 20 years’ experience spanning engineering, manufacturing and commercial roles both in large multinational and startup enterprises, predominantly in the automotive sector.

Gavin has an MEng from the University of Cambridge, and has completed the Business Leaders’ Program at Cranfield University. He is also an Industrial Fellow of the Institute for Manufacturing at the University of Cambridge.

Abstract: Presenting experimental and industrial results of applying NanoDiamond material to improve friction, wear and thermal properties in coatings and composite materials. Fairland Technology is working with Carbodeon, a Finnish nanotechnology company, to develop new applications for this relatively unknown material.

Graphene Oxide Nanocomposites

Toby Sainsbury, National Physical Laboratory

Biography: Dr Sainsbury is currently a Senior Research Scientist in the Materials Division at the National Physical Laboratory in Teddington where he leads a Nanomaterials Laboratory. He has been involved in the area of nanotechnology and nanomaterials chemistry for over 15 years. He holds undergraduate degrees from Dublin Institute of Technology and Trinity College Dublin and a PhD in Physical Chemistry from University College Dublin in the area of nanomaterials chemistry. Dr

Sainsbury completed Post-Doctoral Fellowships in the Fitzmaurice group at University College Dublin, the Zettl group at the University of California at Berkeley and the Coleman group at Trinity College Dublin all in the area of applied nanomaterials chemistry. Specific research has involved nanomaterials for hydrogen storage, sensing and diagnostics, electronics and nanocomposites based on functionalized nanomaterials including carbon nanotubes, boron nitride nanotubes, 2-D nanosheet materials and nanoparticles. Dr Sainsbury has also be involved in fundamental research programs while working at Loctite-Henkel in Ireland, Germany and Austria, and at Nanotechnology start-up companies in silicon valley involving nanocomposites and in the United Kingdom involving thin-film and nanomaterials synthesis.

Current research interests include carbon and boron nitride surface functionalization, 2-D nanomaterials possessing, surface chemistry and chemical integration strategies. Application areas include electronic interconnects, catalysis, energy storage, and nanocomposites for mechanical, thermal, electrical and chemical barrier properties.

Abstract: Recent years have seen tremendous research interest directed towards the emerging area of 2-Dimensional nanomaterials as filler materials in polymer composites. Initial interest has focussed on graphene and the oxidized form; graphene oxide, with specific attention being drawn to the chemical tuning or functionalization of these nanomaterials in order to facilitate dispersion and solution processing in resin and monomer systems and also as a means by which the nanofiller may be chemically bound or integrated to the polymer matrix. It is therefore of particular interest to control the chemical interface between graphene/graphene oxide and the polymer.

Here we report recent advances involving the preparation of functionalized graphene oxide possessing polycarbonate polymer chains covalently bound to the surface of the nanosheets designed for integration into polycarbonate and epoxy systems. Dispersion of the polymer functionalized nanosheets into polycarbonate suspensions over a range of mass fraction loadings has been demonstrated and have been shown to exhibit large increases in mechanical properties. Enhancement in modulus by 25%, ultimate tensile strength by 58%, strain to break from 5% to 180% and toughness increased by 1600% over the base polycarbonate polymer are observed. Analysis of the chemical modification of the nanomaterials indicates that the strategy of tuning the chemicals interface of nanomaterial fillers offers much potential for advanced engineering materials. Specific focus on materials systems for aerospace applications drives this research and offers potential for development materials to be scaled for bulk processing and analysis.

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The Utility of a Nanomaterial Exchange in a Nascent Marketplace and as an Essential Catalyst for Ubiquitous Industry Integration

Tom Eldridge, Fullerex Limited

Biography: Tom is a director and co-founder of Fullerex, a merchant member of INSCX exchange. In his academic background he earned a BSc degree in Physics & Philosophy. Over his professional career however he has worked in the City of London for 7 years in commercial roles with an expertise in market data, financial and regulatory news. Alongside his brother, former stockbroker Joe Eldridge, they founded the company Fullerex in order to drive growth in the market for nanomaterials and create value for customers by identifying and capitalising on technological synergies across industry.

Abstract: One of the main roles of an exchange in any marketplace is to stimulate

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growth. Commodity markets have existed for centuries and were originated not by speculators but by merchants and traders as a tool to for financing production and achieving accurate price discovery. We don't have to go back in history however to see the benefit of commodity markets in transforming resource based economic landscapes. We need only to look at the rapid agricultural growth that is developing across Africa today as a direct result of the introduction of exchanges as institutions of trade.

Nanomaterials have commercially not yet lived up to their considerable promise, as uptake and integration by industry (and ultimately use within everyday products) has been slow progress. Outside of well funded partnership projects, pockets of success have been limited. Many of the causes for this lack of growth pertain to uncertainty in the market through HSE and regulatory issues, lack of agreed material standards, price confusion for buyers, supply insecurity, and often sparse sources of financing for producers. Further to this, most end-buyers looking to integrate nanomaterials into structural and bulk applications (building materials, aerospace and transport, textiles etc) will typically not be geared with relevant laboratory space, specialist compounding facilities, technical expertise or indeed insurance required to process raw nanomaterials and therefore much of that demand exists for composite materials that can be easily applied through existing manufacturing processes.

INSCX exchange as a global marketplace for physical trade of nanomaterials and nanocommodities is a vital tool to understand the demand for nanomaterials and along with its members and partners, bring together various elements of the supply chain, provide key enabling technologies and above all the financing facility in order to respond to that demand.

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