Materials for Composites

Special Interest Group

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Contents

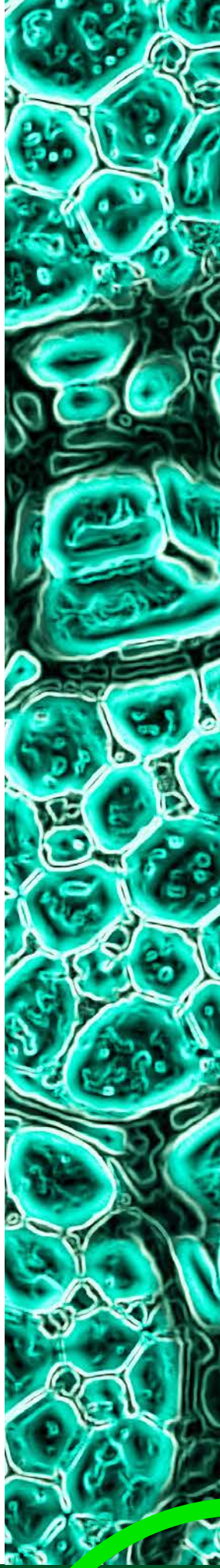
Executive Summary

KTN's Materials for Composites Special Interest Group (SIG) was a year-long project starting in September 2018 which looked at analysing chemical and material suppliers for advanced composites; identifying challenges in material development within the supply chain and opportunities for innovation and collaboration along the supply chain.

The Composites Leadership Forum, an industry-led body, launched The UK Composites Strategy in 2016. This strategy identified an opportunity for the UK composites supply chain and the need for UK investment to accelerate technologies and develop supply chains. Alongside this, the industry-led Chemistry Growth Partnership (CGP now the Chemistry Council) identified composite materials as a key growth opportunity for the UK Chemical Sector. As such, a proposal for a National Composites Centre led by CLF and supported by CGP was developed in consultation with industry, with an initial focus on the aerospace and automotive sectors. Further industry consultation work completed by KTN and the CGP highlighted the need for a Composite Materials SIG.

The Composite Materials SIG would provide a forum for knowledge exchange; community building; technology transfer and collaboration between composites-using sectors and the chemical and industrial biotechnology sectors.

The SIG delivered four networking events across the country in Southampton, London, Manchester and Darlington with a total of 388 attendees. The SIG directly engaged with over 70 companies and made 20 direct introductions which resulted in 4 collaborations. The resulting recommendations were made after working closely with Composites UK, the High Value Manufacturing Catapult (HVMC) and Innovate UK.



Background

Materials for Composites Supply Chain Introduction

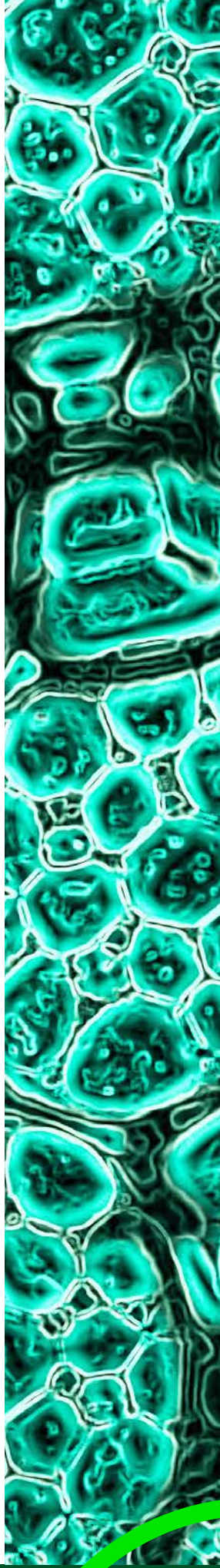
Composite materials are produced from two or more components with different chemical or physical properties which when combined, the resulting composite material has different properties from the individual components used. The individual components remain separate within the finished structure differentiating composites from mixtures, solid solutions and alloys. This report focuses on advanced polymer matrix composites, excluding metal matrix composites and ceramic matrix composites.

The physical properties of an advanced composite material are derived from the combination of fibre reinforcement, polymer matrix and material processing, all of which can be tuned to meet specific material requirements. For this reason, there is a large number of different advanced composites which can be utilised in many different applications. The general properties of advanced composites, for example, lightweight, durable, functional, have led to the deployment of these materials in multiple sectors for a range of applications. The opportunity for advanced materials is expected to increase significantly in the coming years. Figure 1 exemplifies this opportunity by sector.

Figure 1. Forecast figures for UK opportunity in composites, image taken from the CLF UK Composites strategy 2016

There is a complexity within the composites supply chain due to the range of different materials that can be used. The type of resin, reinforcement, coating and additive used to produce an advanced composite will impact how it can be manufactured and the performance of the finished product.

Recent global trends have focused on the sustainability aspects of materials and for advanced composites, this is an increasingly important topic. The Sustainability Working Group (SusWG), which comprises of the Composites UK Sustainability Subgroup and the Composites Leadership Forum Sustainability Group, has recently published A Vision and Roadmap for Sustainable Composites. This aspect of advanced composites is discussed in the sustainability section, and as bio-based feedstocks begin to produce relevant compounds for the industry, there will be increased development activity in this area and a need for alternative supply chains.



Objectives

There were four main objectives of the Materials for Composites SIG:

- To engage with sectors that utilise composites in order to understand their requirements
- To connect composite material suppliers with manufacturing companies that produce engineered composite parts
- To stimulate innovation in the UK upstream supply chain to develop new products that will meet end-user requirements
- To engage with, and complement, existing activities within academia, the industrial base and their associated representative sector bodies, the Composites Leadership Forum, Composites UK and the High Value Manufacturing Catapult (HVMC), in order to foster closer, more effective working relationships.

Scope

As identified in the 2016 UK Composites Strategy (Figure 1) the expected opportunity for composites was not confined to a single sector but spread across multiple sectors with different application areas. The scope of the SIG did not limit activity to a specific sector, however, a recognition that the aerospace and automotive sectors were already engaging the materials supply chain led to an increased focus on other sectors.

The Materials for Composites SIG aimed to develop an understanding of the materials supply chain for advanced composites. This initially included all materials from monomers to intermediate materials. An initial review of UK based chemical companies was completed focusing on monomer and polymer manufacturers, bother thermoplastics and thermosets have been considered. The review identified several global organisations producing monomers for advanced composite materials. However, research and development activities were not UK based. For this reason, the start of the advanced composites supply chain (monomer production) was not investigated further and activity focused on the downstream supply chain from the formulated resins onwards.

Highlights

Landscape

In collaboration with Composites UK, data were collated on companies that identify themselves as part of the composite supply chain. Using the Composites UK Hub information and KTN insights 91 companies have been reviewed and categorised according to the product offering and size. Note that the data set does not include distributors of materials and may not be a complete list. Figure 3 shows graphical representations of the companies reviewed, noting that 63 % of the organisations are SMEs (defined by number of employees).

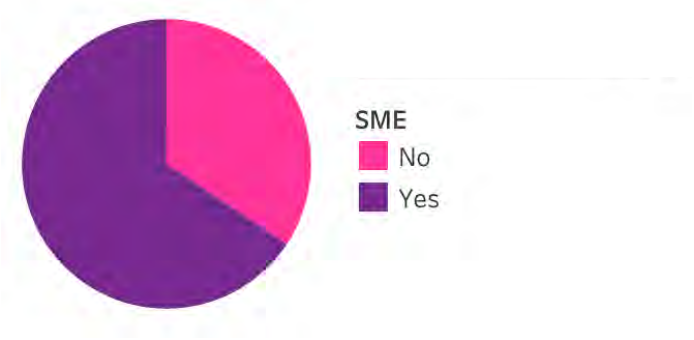


Figure 3. a pie chart showing the percentage of SMEs (63%) and large companies (37%)

Initially, the categories utilised were intermediates, resins, additives, fibres, textiles, core materials and coatings. A company that produces resins and intermediate materials would be included in both categories. Alongside these categories, several companies were found to have an interest in end-of-life activities and bio-based resins. These companies have been identified as contributing to the sustainability of advanced composites materials and are discussed in the Sustainability section. In addition, several companies were identified as producing or developing adhesives for advanced composites.

Figure 4 shows companies identified by the SIG as producing coatings or additives for advanced composite materials. Products within these categories can be utilised in materials beyond advanced composites. This shows that the UK has a strong SME and large organisational presence across coatings and additives in a wide range of geographical locations. Coatings is a particular strength in the UK chemicals sector,

Company Highlight: Thomas Swan & Co Ltd

Thomas Swan's Advanced Materials division is a world leader in the development and supply of carbon nanomaterials and other 2D materials. Thomas Swan's graphene and 2D material products can improve material performance when used as additives in composites and coatings.

and this can be seen in the composites supply chain with 29 companies active in the field, over half of which are large organisations with active research and development activities.

Within the additives field, there are 21 active companies, over half of which are large organisations with multiple markets. For example, different additives can increase the fire, smoke and toxicity performance or introduce colour to the finished product. It is of note that there are several SMEs developing graphene additives for the advanced composites market. The use of graphene in advanced composites has been shown to improve properties like conductivity and material strength.

Figure 4. Maps showing the locations of companies with products categorised as Coatings and Additives. Companies that are SMEs are shown in purple whilst large companies are shown in pink.

The supply chain for reinforcement materials, either fibres or textiles, has not been the main focus of this project. However, within the data set that was analysed, there are a number of companies active in these fields. All of the 10 companies actively involved in fibres (i.e. yarn, roving, strand) were utilising either carbon or glass, with one SME producing recycled carbon fibre. The list of companies active in this area can be found in the appendix. The UK has a stronger presence within textiles however it is of note that this is not a full picture of the UK textiles industry but a subset with an advanced composite focus. Figure 5 shows the locations of textile companies supplying the advanced composites sector.

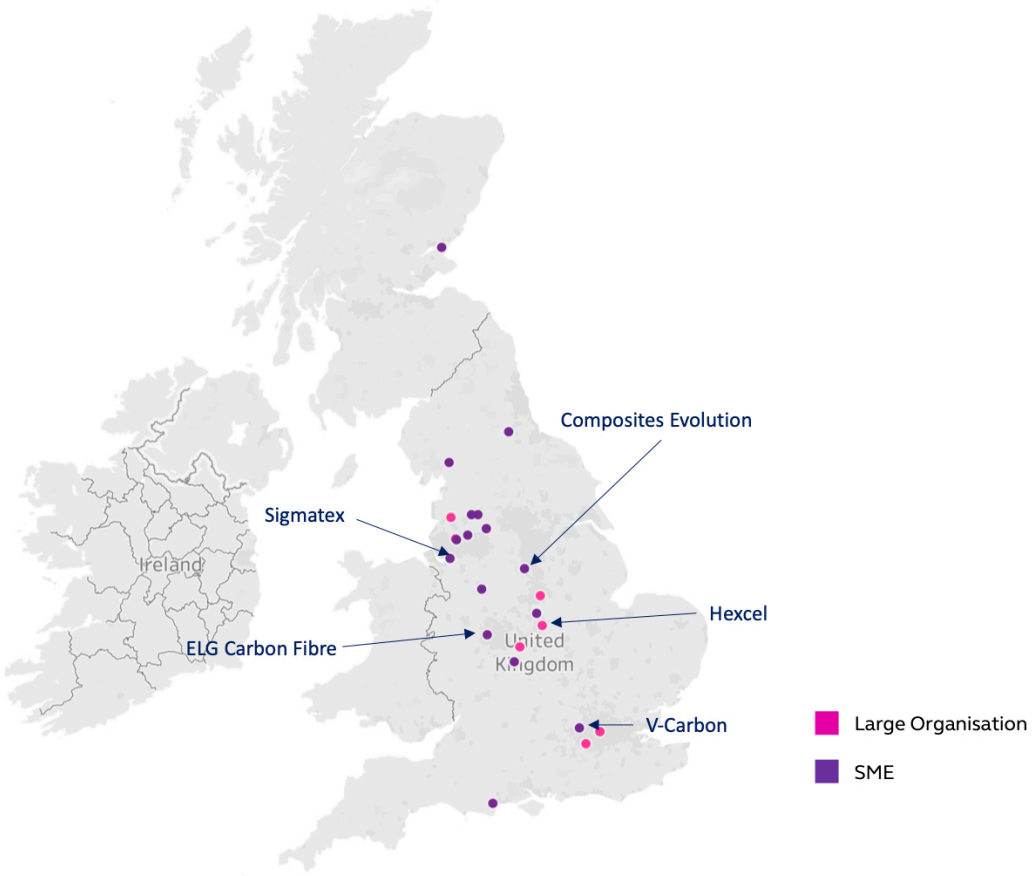


Figure 5. Map showing the locations of companies with products categorised as Fibres and Textiles. The companies highlighted in this figure have been active in the Materials for Composites SIG.

A significant strength in the UK supply chain for advanced composites is the number of companies active in the formulation of resins. These companies formulate different monomers, polymers and additives into highly specified products. Both thermosets and thermoplastics for the advanced composites market are incorporated here. Companies formulating thermoset resins play an integral part in the production of advanced composites and tend to add significant value to the supply chain. This is due to the knowledge required to formulate a resin for a desired specification and performance. This formulation step is generally based on proprietary in-house knowledge and a detailed understanding of the specific chemistry toolbox the company uses. It is of note that a third of companies producing resins are developing or have developed bio-based resins for use in advanced composites. This is discussed further in the Sustainability section.

As per Figure 6, there are fewer companies active in the development of intermediate materials than in the formulation of resins. Whilst a number of these are large multi-national companies, the large majority are SMEs. Figure 6 shows that there is a significant amount of capability in the production of intermediates and in the formulation of resins that could be expanded to meet future demand.

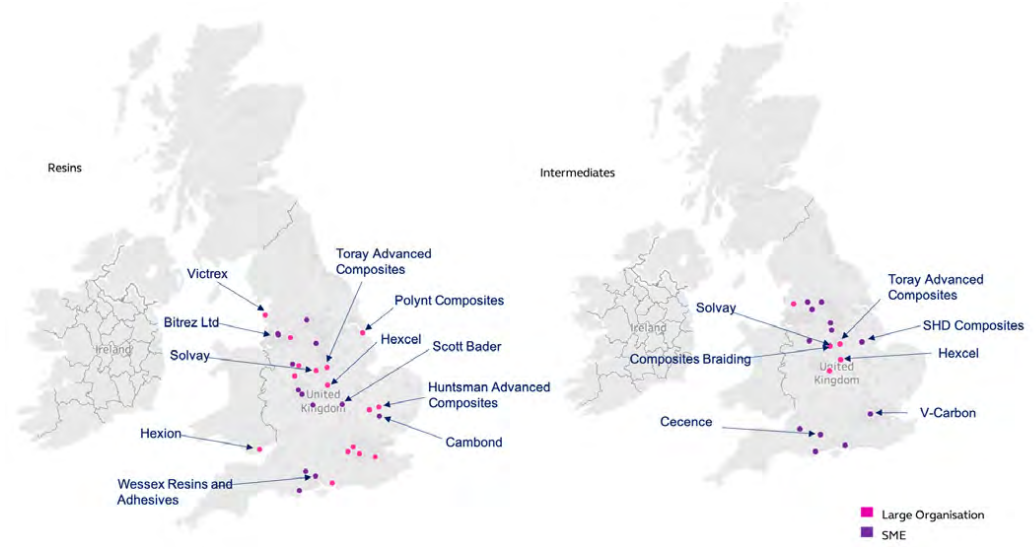


Figure 6. Maps showing the locations of companies with products categorised as Resins and Intermediates. Companies that have contributed to the Materials for Composites Special Interest Group are highlighted in here.

Several companies developing resins or intermediates are also active in other parts of the advanced composites supply chain, including additives and coatings. This allows companies to create added value by providing total solutions to composite part manufacturers. One of the benefits of integrating aspects of the advanced composites supply chain includes an increased understanding of resin chemistry and reinforcement properties. This leads to an increased understanding of the properties of the manufactured part and composite material performance, which can be a challenge associated with advanced composites. The chemicals and materials used alongside the material processing route contribute to the final performance and specification of the composite product. Approaches to addressing this challenge have included integrating parts of the supply chain and developing strong downstream relationships.

Other aspects of the supply chain which have been identified include a company developing surface treatments for fibre sizing; seven companies developing release agents, either mechanical or chemical; and twelve companies providing core materials. These companies have not been analysed further, but details can be found in the appendix.

Strengths can be found in a number of other areas, including coatings,

Company Highlight: Bitrez Ltd

Bitrez, an R&D focused formulator and manufacturer of specialist polymers & synthetic resins has launched a new family of regulatory compliant bio-based resins for the composites industry. Holding the Queens Award for Enterprise in Innovation, Bitrez has developed new grades for both low viscosity and prepreg processing, including bio-Epoxy and Polyfurfuryl Alcohol, both designed especially for composite applications and to meet REACH regulations.

adhesives and additives, where UK companies develop and produce products for multiple applications in different sectors, not just for advanced composites. There is also strength in the textiles supply chain where there are multiple different applications for materials. Further downstream where there is a significant value add in the formulation of resins and production of intermediates. The data indicates there is knowledge and capability which can be built on as the market opportunity grows.

The full list of companies analysed can be found in the appendix. The analysis is not exhaustive and may not include all companies active within the materials for composites supply chain. Should you wish to learn more, be introduced to any companies or be added to the analysis, please contact the author of this report.

Sustainability

The sustainability of advanced composite materials has been a key theme throughout the Materials for Composites project and was identified as an area of interest prior to the SIG commencing. There are two key aspects of consideration when focusing on the sustainability of composite materials: the first is the production of advanced composites using sustainable materials, whilst the second is how advanced composites are treated at end of life. Both of these are areas of interest and have been highlighted during the project. Alongside this, it is noted that there is a need for certain enablers for example, standards for recycled composites, which may increase the development of sustainable composites.

Beyond bio-based resins and end of life options, another consideration in the production of sustainable advanced composites is how to manufacture in a more sustainable way. Reduction of waste and the recycling of solvents are important factors and there are companies active in the UK providing solvent recycling units. The sustainable manufacturing aspect has not been considered in detail within this project.

Sustainable Materials for Composites - Collaboration Building

There has been a significant amount of activity around the sustainability of advanced composites. The Sustainability Working Group (SusWG), which comprises of the Composites UK Sustainability Subgroup and the Composites Leadership Forum Sustainability Group, has published A Vision and Roadmap for Sustainable Composites. This report details a 2040 vision for sustainable composites, identifying 20 topic roadmaps that are key to delivering the vision. Previously KTN has also published the Industrial Biotechnology (IB) and

Bio-based Routes to Sustainable Composite Materials report, which details the technical challenges associated in developing materials for sustainable composites and identifies opportunities for Industrial Biotechnology to provide disruptive solutions.

To build on the work already completed, the Materials for Composites SIG in collaboration with the SusWG hosted the Sustainable Materials for Composites - Collaboration Building event. Prior to the workshop, project ideas related to roadmap topics identified in the 2040 vision were selected as areas for collaboration and action. Topics were developed during the day and aimed to identify challenges, opportunities and existing capability, before considering what might be required to move the topic forward.

Topics discussed included the development of processes for the recycling of glass fibre; the use of waste plastic and fibers in construction materials; integration of supply chains for affordable recycled carbon fibre composites; the development of reactive thermoplastic composites; bio-based fire-retardant chemistries and a bio-based styrene replacement. Whilst the topics are varied there are key themes that can be picked out.

1. The development of chemistries (bio-based or more sustainable products) in order to create more sustainable advanced composites
2. The development of processes to provide end of life options for advanced composites
3. The development of supply chains to deploy technologies and increase adoption of sustainable advanced composites.

During the workshop, it was found that, in most cases, there is a UK capability to develop technology or existing technology that requires further demonstration. Collaborative projects are required to develop and demonstrate the use of advanced composites produced from recycled or bio-based materials. These projects should include the testing of materials in different applications and under different use conditions. This would result in detailed knowledge of material properties and would likely lead to an increase in the adoption of sustainable advanced composites.

Other topics that were developed in the workshop focused on enablers that would increase the adoption of sustainable advanced composites. These included the development of a composites passport, standards for recycled composites and a life cycle analysis (LCA) database. As the UK moves towards a more circular economy, a need to understand how to sort and dispose of products at end of life arises. Alongside this, the ability to assess the full impact of a material or product is required to ensure appropriate design for end-of-life decisions to be made. These are challenges facing multiple sectors and industries, hence connecting with ongoing activity and sharing information as required may accelerate this development.

Some of the topics covered in the Sustainable Materials for Composites - Collaboration Building event are being investigated further by delegates present on the day. If the reader would like further information on any of the topics discussed here, please contact the author of this report. Other topics are also being explored by the High Value Manufacturing Catapult project, ReDisCoveR, which has been developing specific collaborative project ideas focusing on 4 different areas of sustainability for advanced composites - Recycling, Disassembly, Circular Materials and Reuse.

Development of bio-based thermoset resins

A bio-based resin is partially or completely based on monomers derived from biological sources. There are several challenges associated with the development of bio-based materials. These include cost, unknown material properties, raw material consistency and availability of feedstock. Alongside this, the adoption of bio-based materials is also a challenge. However, the development of bio-based resins is an aspect of sustainable advanced composites that a number of resin and intermediate suppliers have been investigating. Figure 7 shows the locations of companies that are known to have developed or be developing bio-based resins for use in advanced composites.

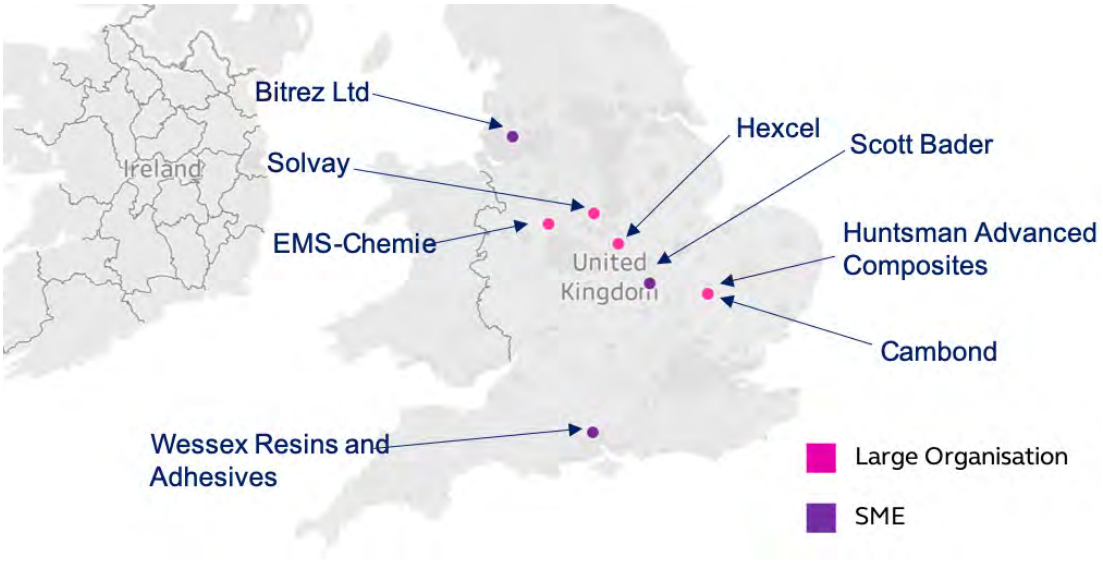


Figure 7. Maps showing the locations of companies known to have or be developing bio-based resins. Companies that are SMEs are shown in purple whilst large companies are shown in pink.

Generally, companies developing bio-based resins are looking to produce products that have better performance specifications than traditional petrochemical-based resins. This may be looking to utilise specific functionality to increase fire, smoke and toxicity resistance or to decrease the use of toxic chemicals in products. This increase in performance allows for the increased

cost that can be associated with bio-based products. Whilst there is interest from multiple sectors in the use of bio-based materials, the current market opportunities are in consumer-facing goods, for example, sports equipment.

Utilising the inherent diversity of bio-based materials offers an opportunity to access different material properties and potentially different applications for advanced composites. This approach is not limited to the formulated resin but could also include the used of bio-based additives to provide specific functionality to the advanced composite. Due to the diversity of bio-based materials and the variety of advanced composites that are produced for multiple applications, supply chain collaboration between current resin formulators, producers of bio-based chemicals and end users will be important for the development of novel bio-based materials for advanced composites. There are also bio-based composite reinforcement options available, for example, hemp or flax fibres which are being actively used in advanced composites for consumer products.

Another consideration that is being raised is the end-of-life options for advanced composites made from bio-based materials. As the circularity of products becomes important, how a bio-based advanced composite is processed at end-of-life needs to be considered, as this will affect the sustainability of the product. As such, design for reusability or recyclability becomes an important aspect of materials development. This links to the need for consistent LCA analysis and an understanding of the impact of a material throughout its use to provide end-users and consumers with appropriate information.

End of life processing

As the use of advanced composites increases, the number of parts reaching end-of-life also increases. With the move to a more circular economy there is a need to address how advanced composites may be reused, repaired or recycled.

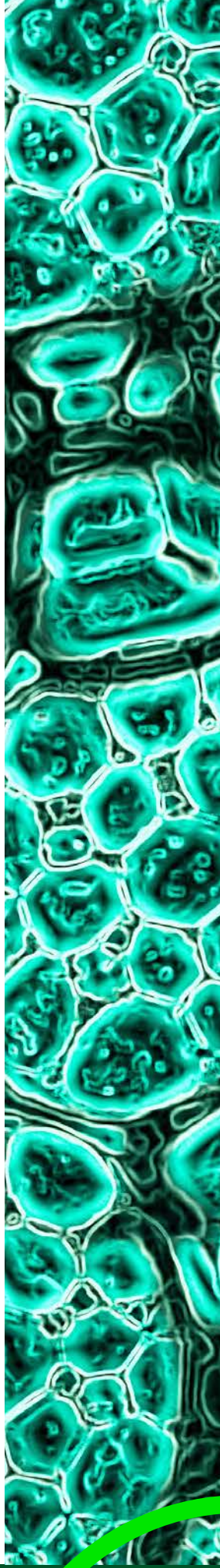
This has been an issue of importance in recent years as a large number of wind turbine blades are expected to be decommissioned over the coming years. Wind turbine blades produced using advanced composites have a lifetime of 20 – 30 years. Currently, collaborative activity between the European Chemical Industry Council and WindEurope is looking to increase the range of recycling options available for wind turbine blades.

Current technology options for processing advanced composites include mechanical processing, pyrolysis and solvolysis, at various stages of development. The challenges associated with each approach are different. One of the main challenges facing any end-of-life processing technology is producing commercially viable products. The types of products that can be produced vary depending on the technology used and can include ground composite, fibres, pyrolysis oil or waste gas.

Recovered fibres can be used to produce different types of textiles for use in advanced composites. Generally, the reuse of fibres is only cost-effective with carbon fibre since the low cost of virgin glass fibre is prohibitive to the introduction of recovered materials. Alongside this, degradation in performance is expected from recovered materials thus, understanding the performance is important in order to target appropriate product applications. This links to the development of standards for recycled materials which would provide confidence in the materials for end-users and increase market uptake. This is an active area in the UK with technology for carbon fibre recovery already deployed and glass fibre technology under development.

Recovery of the materials from the resin through pyrolysis or solvolysis is less advanced due to the number of different degraded products that can be produced during processing. Separation and identification of low molecular weight compounds can be challenging.

The continued development and deployment of end-of-life processing technologies requires collaborative projects to demonstrate how recovered products can be used in different applications and this project should include the waste sector. The development of a composites' passport could act as an enabler for technology deployment.



Challenges and Opportunities

One of the outputs of the Materials for Composites SIG has been the identification of challenges in entering the supply chain and opportunities to collaborate throughout the supply chain. These have been identified through the workshops, the industrial steering group and engagement with companies in the supply chain. These challenges and opportunities have led to a series of recommendations that are aimed at supporting companies in the advanced composites supply chain.

Challenges

Generally, the main challenges identified are market driven not technical and tend to be related to the introduction of new products or materials. The aerospace sector is a significant market for advanced composites and is mature in its use of the materials. However, the qualification of new materials for use in this sector is costly and can take a long time. This can be a challenge for companies looking to enter the aerospace supply chain and develop materials for the sector. As with most supply chain relationships developing an understanding of sector needs and relevant commercial relationships is critical. For small companies with limited visibility to the aerospace sector this can be challenging and when combined with the qualification period, the barrier to entry can be considered too high.

There are different challenges facing the introduction of new materials into other sectors. For example, there are many different applications for advanced composites in construction, however, adoption can be considered slow. There are many different reasons for this. Ensuring that materials and components meet the expected regulations is critical, in cases where appropriate regulations do not exist there is a need to work with regulators to demonstrate materials. In addition, there may be differences in the installation process of the advanced composite components compared to traditional materials and this can present a barrier to entry. Cost is also another consideration and advanced composites are generally considered to be more costly than traditional materials, although may cost less throughout

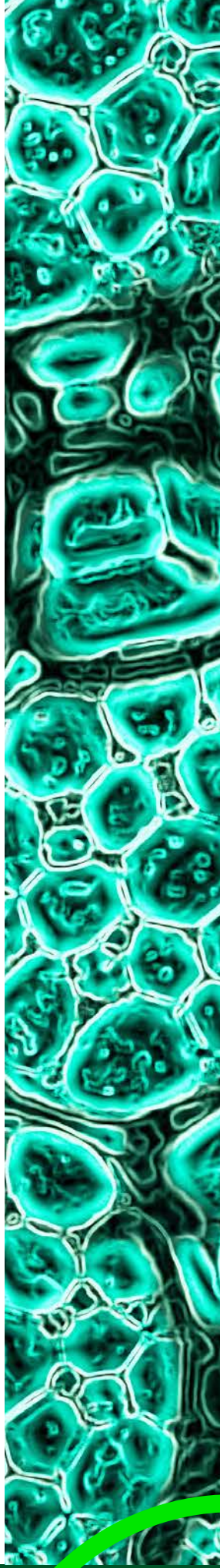
its life. In applications where advanced composites have not yet been shown to provide increased performance or may be more challenging to install, the cost may be the defining factor.

The advanced composites supply chain is complex. This coupled with the diversity of materials that can be produced and the variety of different production methods, offers a wide range of options for end users. This is both a benefit and a challenge. It is likely that a material of the right technical specification can be produced however, finding the appropriate suppliers and understanding the differences between material types may take time. Along the whole supply chain there is an obligation to translate end-user requirements to companies upstream and for new material developments to be tested and explored by downstream companies. This is, therefore, a barrier to new entrants to the market, in particular for upstream material suppliers, for example, those developing new resins or additives specifically for advanced composites. Building a network of collaborators and gaining visibility across the supply chain is important for those companies looking to supply materials.

As noted, the supply chain is complex, however, there is a large amount of knowledge held at each stage. A large number of companies who formulate resins rely on in-house knowledge of the specific chemistries used and formulations required to meet customer specifications. The development of new or improved materials is continuous and based on customer demand, however, there is little focus on collaborative development, particularly when based on current chemistries. There are opportunities for the development of new chemistries and materials for advanced composites which are likely to require a more collaborative approach.

Opportunities

Throughout the course of the project there were several themes that were identified as important to the community. Within each theme there are multiple topics for consideration, these were explored in the final workshop of the SIG. Delegates were asked to prioritise a range of specific areas within the themes and the prioritised areas were subsequently explored in more detail. The areas that were prioritised are detailed in Table 1. It is of note that these themes and topics were largely identified by engagement with companies across the supply chain with the exception of the reinforcements theme.



Theme	Topic areas
High Volume Manufacturing	– Developing thermoplastics for high volume manufacturing – Developing thermosets for high volume manufacturing
Sustainable Composites	– Use of bio-based materials in composite manufacturing – Reuse / Recycling options for end of life
Modelling	– Modelling of new formulations and resulting properties – Modelling of resin properties to component properties
Translation of low TRL R&D into products	– Development of new materials – Scale-up of new materials – Engineering of new products
Reinforcements	– Fibre sizing for high temperature matrices – Fibre sizing for recycled materials – Modification to surface chemistry of legacy fibres – Chemistry for future reinforcements

Table 1. Themes and topic areas which were prioritised during the final SIG workshop.

Table 2 shows the number of votes obtained by the four highest scoring topics and analysis of the voters. In this case 'Other' represents trade associations, RTOs or Government organisations. During the workshop, the two topics within high volume manufacturing were combined based on feedback from delegates. The analysis of votes has led to two main conclusions. Firstly, there are topics which offer opportunities for collaborative research i.e. modelling of resin properties and development of new materials. Secondly, the development of materials for high volume manufacturing is of importance to industrial representatives.

Topic area	Total	Industry	Academia	Other
Development of thermoplastics and thermosets for high volume manufacturing	14	7	1	6
Modelling of resin properties to component properties	11	4	3	4
Development of new materials	9	5	4	0
Reuse / Recycling options for end of life	8	0	2	6

Table 2. Analysis of prioritisation votes for top 4 topics

The top four topic areas were developed in further detail during the workshop to identify opportunities and gaps. A summary of the discussion on each topic is detailed here.

Development of thermoplastics and thermosets for high volume manufacturing

The development of thermosets and thermoplastics for high volume manufacturing is beginning to be explored by different organisations. This is currently of particular interest to the automotive sector which is looking into light-weight vehicles. This becomes increasingly important as more electric vehicles are produced, since decreasing the weight of a vehicle should result in an increase to vehicle range. Achieving high volume manufacturing for the emerging automotive market may also have an effect in other sectors and increase the adoption of advanced composites.

There are many different challenges associated with this from materials development to process manufacturing and standardised materials. In addition to this there is a need to consider the economics. It is possible that materials that could be used in high volume manufacturing processes can be formulated using current chemistries, however, if these materials cannot be produced at a cost acceptable to the automotive market, adoption of advanced composites will remain low.

In order to achieve high volume manufacturing of advanced materials, a collaborative research and development programme with a cross-sector, cross-disciplinary approach is required. There is an opportunity to bring together materials and process development research to develop manufacturing processes in an agile, fail fast approach which would meet the manufacturing requirements of the automotive sector. There is also a cross-sector opportunity for advanced composites to learn from other sectors that have moved towards automation. This would offer an opportunity to share learnings and potentially upskill parts of the advanced composite sector.

Development of New Materials

Closely linked to the topic of developing new thermosets and thermoplastics for high volume manufacturing is the topic area focusing on the development of new materials. New materials for composites are continuously being developed by companies along the supply chain, generally driven by customer requests and based on known chemistries. There is an opportunity to develop new materials which can provide improved properties for the demands of emerging markets, for example, increased fire, smoke and toxicity resistance in the construction sector.

A programme of activity connecting end-users and their material requirements to academics and material suppliers to identify, test and develop new materials could allow for advanced composite materials with increased performance which could unlock additional opportunities in new and current sectors. This is of particular importance to SME innovators in the sector, as the testing of new chemistries and materials at an early stage would accelerate the delivery of new products to market.

Modelling of resin properties to component properties

The modelling of resins and components was identified as a topic area of interest by academia and industry. Modelling capability to link through material design, resin formulation, component properties and material life-time would decrease the development time for new formulations, increase understanding of how resin properties are linked to component properties and ease the adoption of advanced composites by allowing for more accessible design.

To develop consistent models across multiple scales and parameters, cooperation across the research and industrial communities will be required. There is currently a gap in the scientific understanding which would allow for appropriate models to be produced, coupling academic understanding to materials characterisation techniques and test methods would improve capability in this area. It is likely that some aspects of the fundamental understanding could be applied to other materials having an impact beyond advanced composites. Providing access to a centralized open source of data

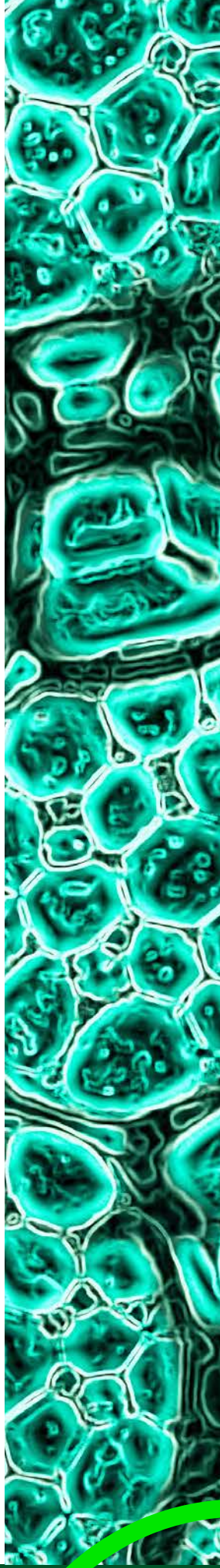
may lead to increased research and development in this area however this would raise confidentiality concerns and may only be supported by industry in defined areas. Emerging AI and big data techniques may provide alternative ways to access and share information to benefit the wider sector and should be considered.

The successful development of models which can be used to enable product design, ease material selection and provide component parameters would have a significant impact on the industry by decreasing product development times, reducing testing costs and increasing confidence in advanced composites for the composite using sectors. Investment in fundamental research and projects with defined testing partners along the supply chain and clear feedback routes could be one approach to developing these models. This could be through a joint EPSRC and Innovate UK call with models developed by academia which would then be validated and tested by industrial partners.

Reuse / Recycling options for end of life

The final topic area covered during the workshop was the reuse and recycling options at end-of-life. This is a topic of high importance for the sustainability of advanced composites and has been discussed in the Sustainability section of this report. There is technology being developed within the UK around the processing of composites at end-of-life, however, one of the key challenges in this area is the identification of applications for materials produced in the recycling process. The identification of applications and the development of a market for the recycled materials is key to the successful reprocessing of advanced composites. This can be supported by changes in legislation leading to increased recycling of materials, the development of standards for recycled materials and increased knowledge of recycled materials and their properties.

The High Value Manufacturing Catapult (HVMC) currently has an extensive largescale transformation project active in this area, called ReDisCoveR the project is covering the Recycling, Disassembly, Circular Materials and Reuse of advanced composite materials. This project is investigating specific details in each of these areas with the aim of developing project ideas and collaborations. For further information please see the resources section or contact the author of this report.



Learnings and Recommendations

The data presented here shows that there are strengths and weaknesses in the UK supply chain for advanced composites. Most notably, there are weaknesses in the upstream supply chain - specifically the production of monomers for the polymer matrix resins and in precursors for fibres, development in these areas tend to occur overseas.

Companies that formulate resins tend to work with customers in order to meet the target specifications and this continuous development of new resins allows for improvement in product performance. There is a significant amount of knowledge and product development occurring within companies that formulate resins for advanced composites. However, due to the proprietary nature of resin formulation there is little cooperation between companies outside of the traditional customer and supplier relationships.

Companies active in the formulation of resins would be supported by research into the modelling of formulations, this would be utilised by industry to enable faster development of resins. In addition, academic research into new materials (monomers, polymers and additives) being translated into industrial applications, could provide opportunities for companies to increase their technical capability and further impr ove material performance.

One of the challenges associated with developing new materials, in many industries, not just composites, is the balance between cost, performance and scale. The use of new materials in the development of product prototypes is critical to demonstrating the performance of new materials for use in advanced composites.

The learnings developed throughout the SIG have led to a series of recommendations aimed at accelerating innovation across the supply chain.

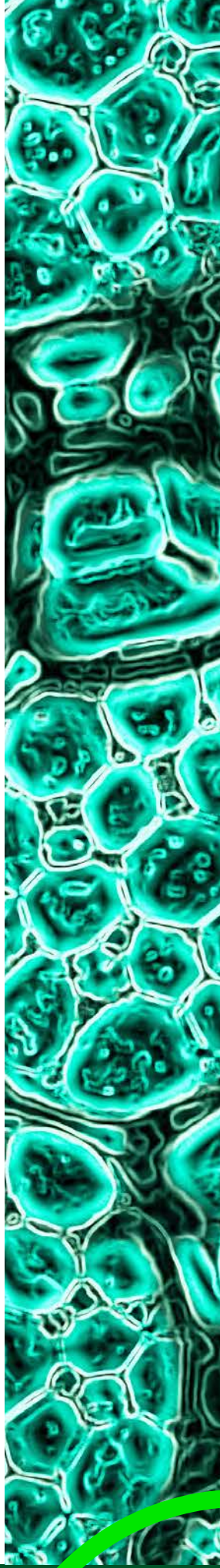
1. Collaborative R&D funding to develop materials and products for specific applications through supply chain cooperation and collaboration.

2. A programme of fundamental research and collaborative R&D projects connecting composite using sectors and their material requirements to academics and material suppliers.

3. Development of applicable computational models through academic and industrial collaborations.

4. Public support and private investment to develop end of life processes, produce products from recycled composites and identify bio-based materials that can be used in advanced composites.

5. Knowledge transfer in small dedicated focus groups could be used to explore specific market segments or technologies in order to accelerate adoption across sector.



Deliverables

Deliverable	Comments
Cross-Sector Industry Steering Group (ISG)	Organised a cross-sector industry steering board with representatives from across the advanced composites supply chain.
Workshops	Held 4 technology transfer workshops providing opportunities for networking and collaboration. See appendix for further details
Landscape Map	Identified companies in the material supply chain for advanced composites.

KPIs and Outcomes

72 Company Engagements

20 Introductions

4 Collaborations

Resources and Further Reading

- The 2016 UK Composites Strategy
- A Vision and Roadmap for Sustainable Composites
- IB & Bio-based Routes to Sustainable Composite Materials
- High Value Manufacturing Catapult project ReDisCoveR
- Accelerating Innovation for Chemistry in Composites

Contacts and Acknowledgements

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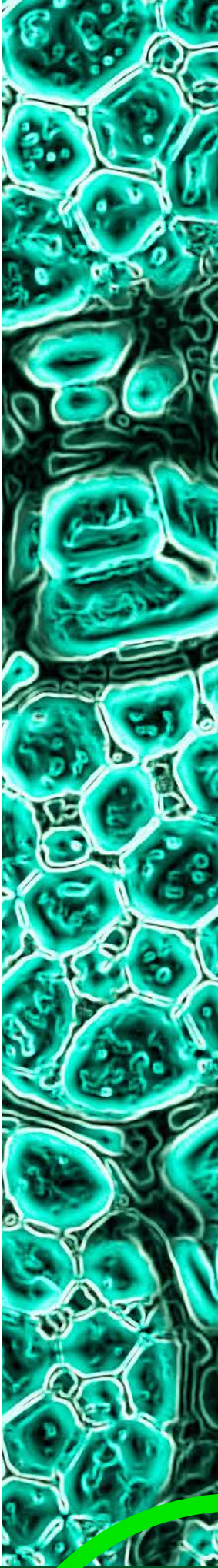


Appendix 1

List of Companies Analysed

Organisation Name	Location	Resins	Bio-based Resins	Fibres	Textiles / Fabric	Additives	Core Materials	Intermediates	Adhesives	Coatings	Recycling	Sizing	Release Agents
3M United Kingdom plc	Bracknell					x			x	x			
Advanced Insulation Systems Ltd	Gloucester									x			
AkzoNobel	Slough									x			
Alan Harper Composites Ltd	Saltash					x							
Alchemie Ltd	Warwick	x							x	x			
Aptec Products Ltd	West Auckland				x						x		
Aviation Composites	Alton						x						
Axion Polymers	Manchester										x		
BASF PLC	Cheadle	x				x				x			
Biscor Ltd	Bradford								x				
Bitrez Ltd	Wigan	x	x										
Büfa Composite Systems	Ince	x		x	x	x	x		x	x			x
Cambond	Cambridge	x	x										
Cecence Ltd	Salisbury	x						x					
Central Tapes & Adhesives Ltd	Sutton Coldfield								x				
Changing the Face of Composites	Congleton									x			
Chem-Trend (UK) Ltd	Huddersfield												x
Chomarat Textiles Industries	Esher				x		x			x			

Organisation Name	Location	Resins	Bio-based Resins	Fibres	Textiles / Fabric	Additives	Core Materials	Intermediates	Adhesives	Coatings	Recycling	Sizing	Release Agents
Coats Speciality	Uxbridge			x	x								
Composite Braiding Ltd	Derby							x					
Composites Evolution Ltd	Chesterfield				x			x					
Coretex Group	Cheltenham						x						
Croda	Goole					x			x	x			
Custom Composites Ltd	Rochdale						x						
Deltech Europe Ltd	Haverhill	x								x			
DIAB Ltd	Gloucester						x						
Dow Chemical Company Ltd	Staines	x				x			x	x			
Easy Composites Ltd	Stoke-on-Trent	x		x	x	x	x	x	x	x			
ELG Carbon Fibre Ltd	Coseley			x	x						x		
Elmira Ltd	Sheffield	x				x		x					
EMS-Chemie (UK) Ltd	Stafford	x	x										
Estakleen Systems Ltd	Wimborne										x		
Evonik Resource Efficiency GmbH	Milton Keynes	x				x	x		x	x			
Farecla Products Ltd	Ware									x			
Fiba Tech Industries Ltd	Waterlip							x		x			

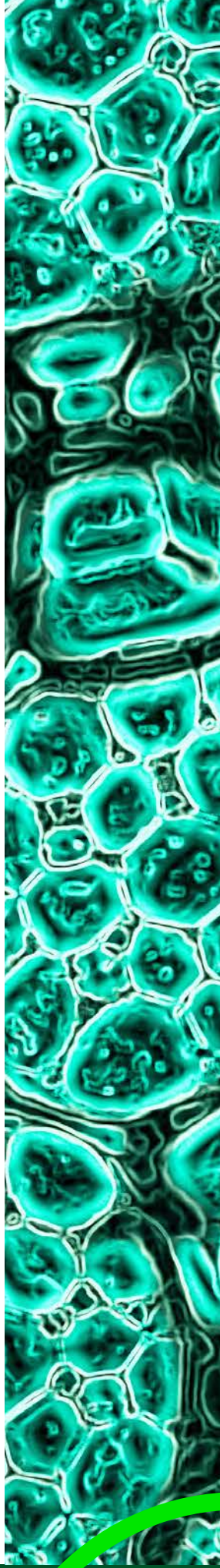
Organisation Name	Location	Resins	Bio-based Resins	Fibres	Textiles / Fabric	Additives	Core Materials	Intermediates	Adhesives	Coatings	Recycling	Sizing	Release Agents
First Graphene (UK) Ltd	Manchester					x							
Fothergill Engineered Fabrics Ltd	Littleborough				x					x			
Gurit (UK) Ltd	Newport	x			x		x	x	x	x			
Haydale	Ammanford					x							
Hexcel Ltd	Duxford	x	x	x	x	x	x	x	x				
Hexion UK Ltd	South Glamorgan	x				x			x	x			
Hexpol TPE	Manchester	x											
Huntsman Advanced Materials	Cambridge	x	x						x				
James Dewhurst	Altham				x								
Jones Stroud Insulations Ltd	Preston				x			x					
Kisling AG	Cardiff								x				
Llewellyn Ryland Ltd	Birmingham					x				x			x
M Wright & Sons Ltd	Loughborough				x								
Magnum Venus Products Europe Ltd	Brierley Hill										x		x
Marbocote Ltd	Middlewich												x
Menzolit Ltd	Burnley							x					
Mitsubishi Chemical Carbon Fiber and Composites GmbH	Coventry			x	x			x	x				
N12 Europe Ltd	Hythe					x							
Nippon Electric Glass Co Ltd	Wigan			x	x	x							
NSG	St Helens					x							

Organisation Name	Location	Resins	Bio-based Resins	Fibres	Textiles / Fabric	Additives	Core Materials	Intermediates	Adhesives	Coatings	Recycling	Sizing	Release Agents
Oxford Advanced Surfaces Ltd	Begbroke											x	
Parkhill Textiles Ltd	Burnley				x								
Permabond Engineering Adhesives Ltd	Winchester								x				
Polynt Composites UK Ltd	Near Grimsby	x				x			x	x			
Porcher industries	Littleborough			x	x			x					
PPG	Shildon									x			
PRF Composite Materials Ltd	Poole	x			x			x		x			x
Project 12 Ltd	Banbury									x			
Quin Global (UK) Ltd	Perth								x				
Reichhold UK Ltd	Mitcham	x								x			
SciGrip Adhesives Ltd	Washington								x				
Scott & Fyfe Ltd	Tayport				x								
Scott Bader Company Ltd	Wellingborough	x	x							x			
SHD Composite Materials Ltd	Sleaford							x					
Sigmatex (UK) Ltd	Runcorn				x						x		
Sika Advanced Resins	Newmarket	x					x		x	x			
SJA Film Techlogies Ltd	Accrington												x
Solvay Group	Heanor	x	x	x	x			x	x	x			
Sumike Polymer Compounds	Havant	x											
Sumitomo Bakelike Company Ltd	Stansted	x											

Organisation Name	Location	Resins	Bio-based Resins	Fibres	Textiles / Fabric	Additives	Core Materials	Intermediates	Adhesives	Coatings	Recycling	Sizing	Release Agents
Talga Techlogies Limited	Cambridge					x							
Techlan Ltd	Swansea										x		x
Technical Fibre Products Ltd	Kendal				x								
Thomas Swan & Co Ltd	Consett					x							
Toray Advanced Composites UK Ltd	Nottingham	x			x	x		x		x			
Toray International UK Ltd	London				x								
Total Composite Solutions Ltd	Havant	x						x	x				
Trident Foams Ltd	High Peak						x						
V-Carbon	London							x			x		
Valmiera Glass UK Ltd	Sherborne			x	x								
Victrex	Thornton Cleveleys	x											
Von Roll UK Ltd	Bradford	x						x	x				
Wessex Resins & Adhesives Ltd	Romsey	x	x						x				
Whitford Ltd	Runcorn									x			
William Blythe	Harlow					x							
Zircotec Group	Abingdon									x			

Events

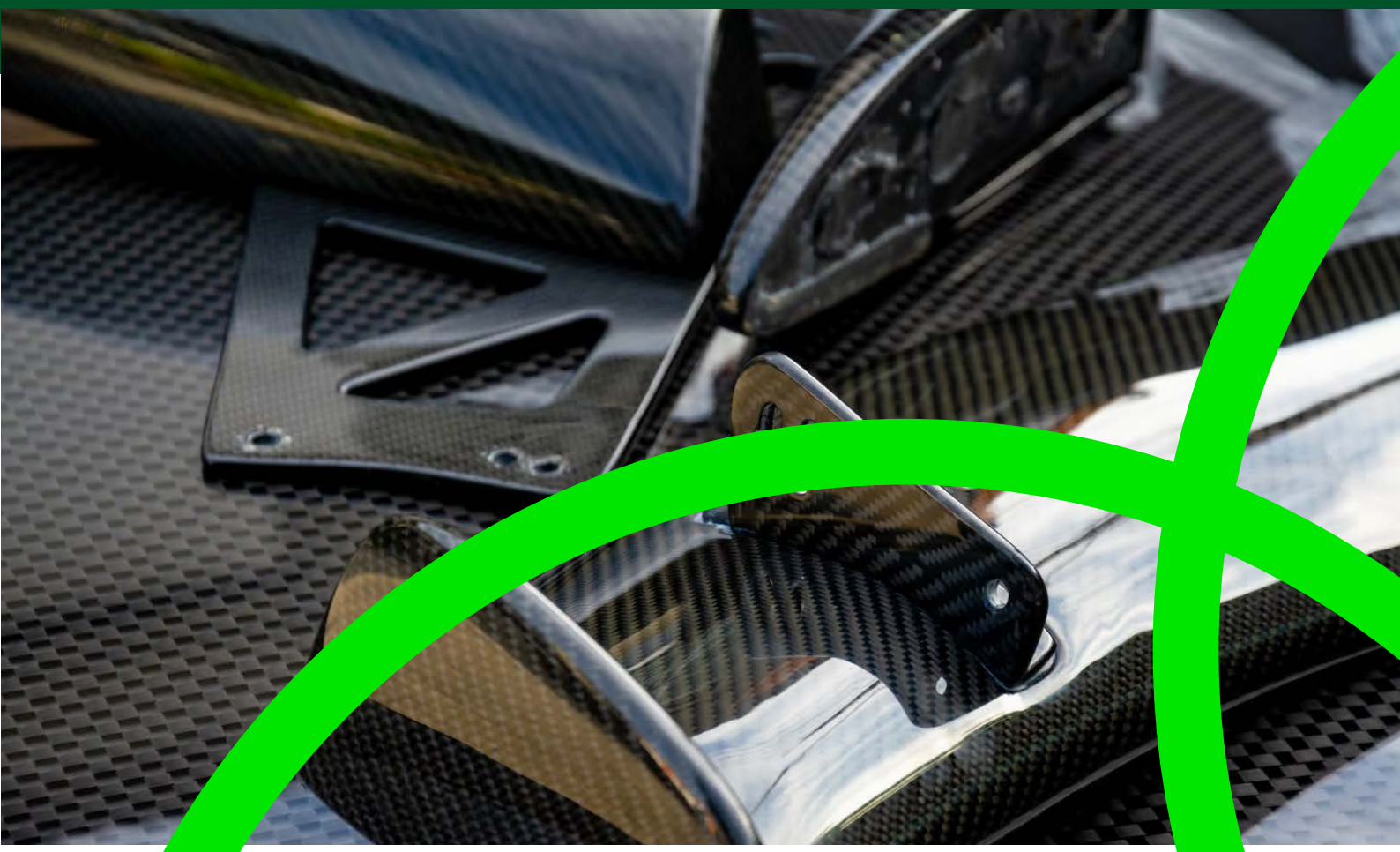
Event Name	Location	Theme	Registered Delegates
Materials for composites networking event	Southampton	Launch event and Networking	123
Sustainable Materials for Composites Collaboration Building Event	London	Sustainable Composites	91
Next Generation Composite Matrix Materials Conference	Manchester	New Materials	110
Growing UK Supply Chains for Materials and Components in Advanced Composites	Darlington	Industry Needs	64



Connecting for Positive Change

KTN exists to connect innovators with new partners and new opportunities beyond their existing thinking – accelerating ambitious ideas into real-world solutions.

The world we live in faces ever-changing societal, environmental and economic challenges, which are felt regionally, nationally and also globally. At KTN our mission is to connect ideas, people and communities to respond to these challenges and drive positive change through innovation.



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