# Ceramic Matrix Composites Opportunities

LUCIDEON

NATIONAL COMPOSITES CENTRE

# Introduction

**Advanced composites demand complex processing techniques to maximise their performance.**

Lucideon and the National Composites Centre (NCC) are working in collaboration to develop advanced ceramic matrix composite (CMC) solutions that meet a growing market demand for materials that excel in ever harsher environments. From energy to defence, space, or aerospace, our combined expertise offers a comprehensive range of services in the use of oxide and non-oxide CMC materials across a variety of applications.

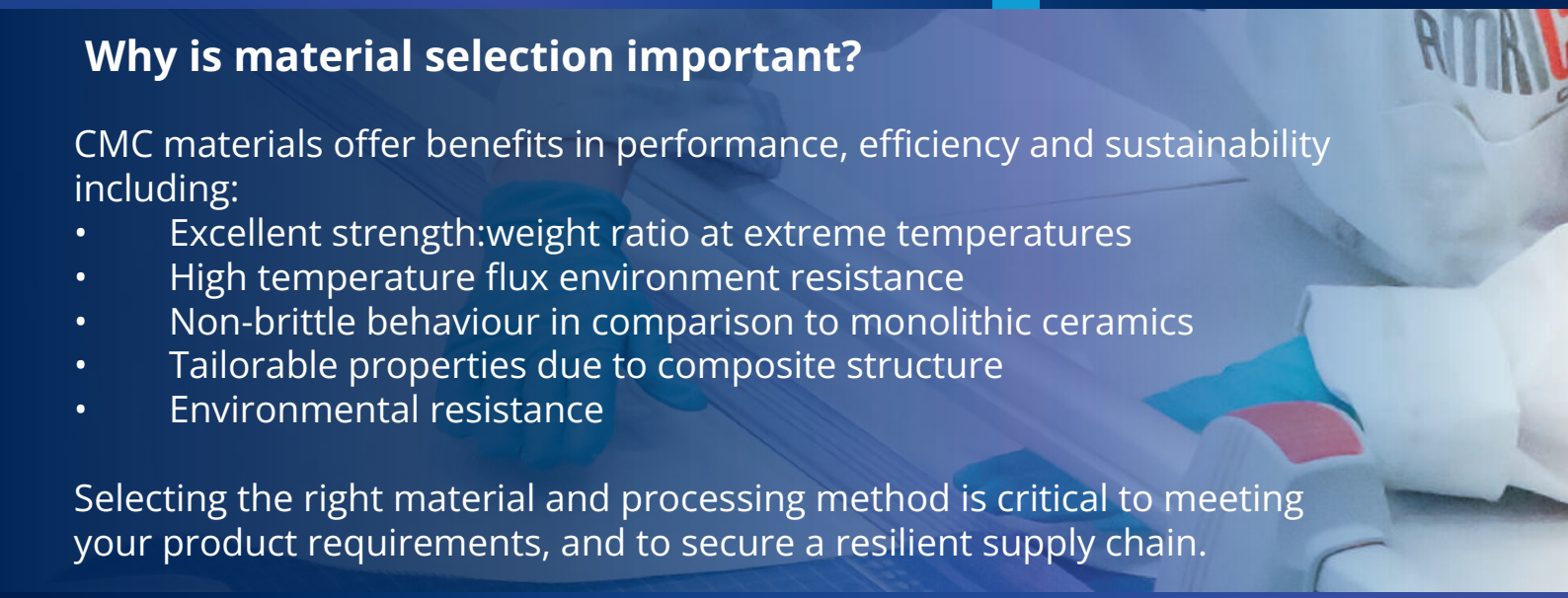
Lucideon can develop these advanced materials, from formulations optimisation to sintering process enhancement, and offer in-house excellence in analysis and evaluation services. As a world-leading UK research and development facility, and the UK's centre of excellence for composites, the NCC offers a full range of services across the engineering lifecycle with access to industrial scale technology, all in one place.

Together, the collaboration offers end-to-end capability for developing and exploiting supply chain organisations' technologies, addressing CMC adoption challenges from fundamental materials development through to full system design and validation.

# CMC Development Steps

1. Material Selection
2. Design
3. Matrix Preparation
4. Fibre Layup & Impregnation
5. Heat Treatments
6. Densification
7. Post-Production
8. Testing

# 1. Material Selection



## Why is material selection important?

CMC materials offer benefits in performance, efficiency and sustainability including:

- Excellent strength:weight ratio at extreme temperatures
- High temperature flux environment resistance
- Non-brittle behaviour in comparison to monolithic ceramics
- Tailorable properties due to composite structure
- Environmental resistance

Selecting the right material and processing method is critical to meeting your product requirements, and to secure a resilient supply chain.

## Capability:

We use best practice in down-selection methodologies, coupled with vast experience in advanced materials processing, to recommend the most feasible outcome for your requirements. Lucideon and the NCC share extensive knowledge in:

### Ceramic fibres

- Enabling access to domestic and global supply chains
- Material knowledge:
  - Carbon based (C)
  - Silicon carbide based (SiC)
  - Oxide based (Ox), including Alumina and more

### Ceramic matrices

- Enabling access to a dedicated CMC development facility in the UK
- Material knowledge:
  - Silicon carbide based (SiC)
  - Oxide based (Ox), including Alumina and more
  - Ultra-high temperature ceramics
- Manufacturing processes:
  - Polymer impregnation and pyrolysis
  - Chemical vapour infiltration
  - Automated fibre technology
  - Liquid silicon infiltration
  - Hot pressing

# 2. | Design

## Why is design important?

A fit-for-purpose design safely minimises development time and cost, and significantly reduces the amount of physical manufacturing trials required to refine and verify a product.

## Capability:

As a pioneer in UK composites technology, the NCC's dedicated in-house CMC development facility specialises in composites design and manufacturing processes, understanding how to maximise their potential and unlock innovation. The latest tools and techniques progress indigenous UK innovation from concept to detailed analysis, ready for manufacture. This includes the design and manufacture of complex, large-scale components for trusted innovation partners in aerospace, defence, and energy.

End-to-end engineering services include:

- Sovereign composite component design
- Design for manufacture
- Tooling design
- Structural analysis
- Analytical methods
- Sustainability

# 3. Matrix Material Preparation

## What is matrix material preparation?

Materials must display a very particular set of properties to be suitable for matrix impregnation. Correct viscosity, particle size distribution, and rheology characteristics are necessary to achieve uniform distribution throughout the end-product to ease processing and maximise performance.

Through precise preparation of the matrix material, these characteristics can be calculated, verified, and made replicable.

## Capability:

This is where Lucideon's core expertise and capabilities lies. Our access to the pilot-scale equipment located at The AMRICC Centre, a Centre of Excellence for Advanced Ceramics hosted and managed by Lucideon, allows us to design and undertake end-to-end trial processes including milling, mixing, and slurry characterisation.

Lucideon can develop new formulations and systems aimed at tailoring viscosity for impregnating and infiltrating the matrix into the fibre preforms as effectively as possible.

# 4. Fibre Lay-Up & Impregnation

## What is fibre lay-up & impregnation?

Fibre provides strength and stiffness to the matrix material, while impregnation enables support, bonds, and protection to the fibre. Fibre orientation and location, combined with resin systems alter the properties of a matrix.

## Capabilities:

The NCC is equipped with advanced composite cutting and placement machinery to guarantee precise fabric deposition. This preformed fabric can then be infused using various pressure-assisted injection units, suitable for anything from lab-scale experiments to full-scale production.

Technology available:

- Automated composite cutting
- Digital layup tables
- Automated fibre placement
- Range of industrial presses
- Selection of suitable injection equipment
- Advanced preforming technologies

# 5. Heat Treatments


## What are heat treatments used for?

Once an impregnated fibre architecture is created, various heat treatments are deployed for further processing, consolidating the part and burning off binders and additives before final densification occurs.

## Capabilities:

Lucideon can provide pilot-scale trials through autoclave consolidation and drying processes and can develop binder systems for enhanced green strength. Lucideon can help to optimise the debind and pyrolysis process through thermal analysis and pilot-scale furnaces.

Both the NCC and Lucideon have access to autoclaves for green part formation.

By 2025, the NCC will also offer a large component level pyrolysis furnace.

# 6. | Densification

## What is densification?

Densification is the process of reducing the porosity of a composite, with the desired goal of making the final product more compact. Densification is achieved by filling pores with additional material or by compressing existing material using pressing or other technologies.

## Capabilities:

Lucideon offers capabilities in current technologies such as hot isostatic pressing (HIP) and hot pressing at up to 2,200°C. As a development and commercialisation organisation, Lucideon also supports the development of alternative densification techniques such as sol-gels, polymer pyrolysis, and liquid silicon infiltration.

Through The AMRICC Centre, Lucideon has access to a large Ox/Ox sintering furnace. Viewing ports on the furnace enable the use of computer vision and computational modelling techniques to understand and predict material distortion during sintering.

Lucideon and the NCC possess in-house capability to develop novel techniques such as Polymer Impregnation Pyrolysis, and have links to the wider CMC industry for chemical vapour infiltration methods amongst others.

# 7. Post Production

## What options are available post-production?

Although CMCs can display extreme resilience against thermal shock and other factors, some end-use applications require additional factors to compensate for their vulnerabilities in other areas such as hot steam environments or oxidation.

## Capability:

Lucideon is developing Contactless Flash Sintering, a surface sintering technique suitable for use in Environmental Barrier Coatings and other applications which produces a homogeneous layer of coating whilst maintaining the desired microstructural control.

Lucideon has expertise in the development and processing of coatings, including the development of environmental and thermal barrier coatings with matching thermal expansion coefficients, glass ceramics and glazes.

Novel bonding systems are needed for joining dissimilar materials, particularly for materials with different coefficients of thermal expansion. Lucideon is developing novel bonding systems to help overcome this challenge.

The NCC serves as a gateway to the wider High Value Manufacturing Catapult network to further technology innovation. Through the Centre of Expertise in Advanced Materials and Sustainability (CEAMS), the NCC also supports the development and commercialisation of advanced sustainable materials.

Both organisations have close links to partners offering machining capabilities.

# 8. Testing

## Why is testing significant?

CMCs possess extraordinary characteristics that mark them as suitable for applications in extreme environments. The crucial roles that these materials may fulfil therefore requires absolute confidence in their performance and reliability, necessitating rigorous testing to validate their resilience to heat, corrosion, strain, and myriad other factors.

## Capabilities:

Lucideon has expertise in the characterisation and testing of advanced ceramic materials, offering microstructural, chemical, and thermal analysis, and mechanical testing (up to 1600°C).

With access to the latest non-destructive testing (NDT) technologies, the NCC's verification capabilities range from polymer thermal behaviour characterisation to mechanical and environmental performance testing.

Alongside Lucideon's mechanical testing capabilities, both organisations have close links to partners offering further mechanical testing at elevated temperatures of 1200°C and above.

NATIONAL COMPOSITES CENTRE

## About NCC

The National Composites Centre is a world-leading UK research and development facility that provides access to state-of-the-art engineering capabilities and technology. Collaborating to address the most complex engineering challenges of our time, we accelerate the development of new products across advanced materials, digital engineering, sustainability, and hydrogen.

Delivering pioneering innovation to drive industrial transformation, NCC works across a diverse range of sectors to deliver benefit to the UK, investing in the talents of our current and future workforce.
Part of the High Value Manufacturing Catapult, it collaborates with innovators to SMEs, the supply chain, and OEMs, providing businesses with a de-risked environment to design, develop, test, and scale their ideas and get to market fast.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## About Lucideon

Lucideon is a development and commercialisation organisation (DCO), specialising in materials technology, processes, and testing. Its application of cross-industry insight, materials science expertise, and innovative thinking allows industry to develop and implement disruptive technology platforms, providing cost and/or product performance benefits and enabling real market differentiation. It utilises its many years of experience in development, analysis, and assurance to provide technical consultancy to enable, enhance, and accelerate its clients' R&D activities.

In addition to a multi-disciplinary team of scientists, engineers, and commercial analysts, Lucideon has world-leading testing and characterisation laboratories, a combination of pilot and feasibility plant and equipment, and a management and certification division.

Lucideon has offices and approved laboratories in both North and South Carolina, as well as New York State, and Staffordshire in the UK.


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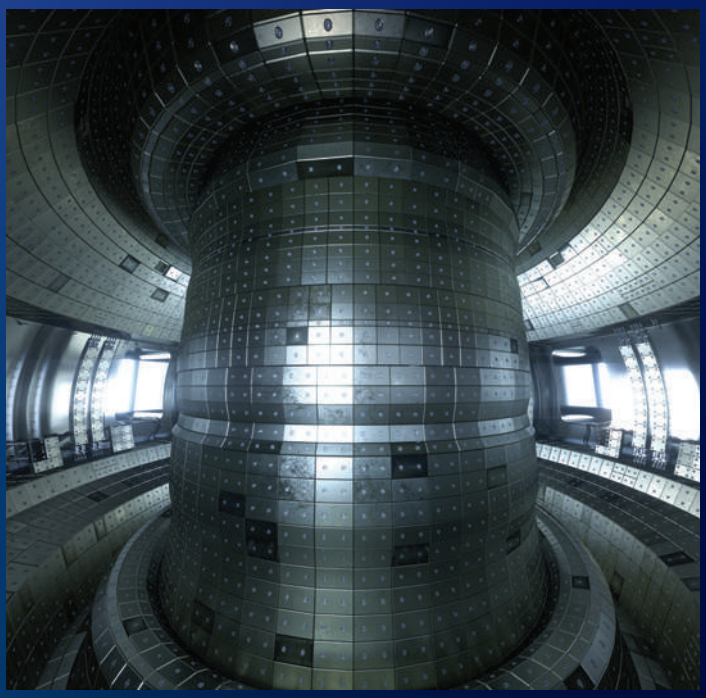
# Case Studies

## CMCs for energy

The NCC is working with the UK Atomic Energy Authority on the HASTE-F programme, sharing knowledge and expertise in the application of silicon carbide composites (SiC/SiC) as a fusion material. NCC have identified a step change in SiC/SiC manufacturing that has the potential to transform the fusion sector, developing an efficient, scalable, and cost-effective manufacturing route for 'fusion-grade' SiC materials. The use of SiC/SiC composites enables twice the electricity from fusion-generated heat.



## Preparing for hypersonic speeds

Together with MBDA, the NCC launched the 'MBDA Ceramic Matrix Composite Airframe Technology Challenge' to identify novel CMC materials and manufacturing methods for next generation airframes. With the future of flight set to be hypersonic, the challenge sought to develop a proof of concept that could operate at the elevated temperatures higher speeds bring. Developing and scaling novel UK materials and manufacturing processes within the Challenge demonstrated how the NCC can support critical programmes in the UK defence sector, unlocking the ability to identify technologies and innovate quickly with sovereign businesses.

*Commercial confidentiality prevents inclusion of any Lucideon case studies*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