CMCs for Nuclear Fusion Energy Applications

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Why Nuclear Fusion Energy?

By 2050, the planet could be using twice as much electricity compared to today. More people (an increase from seven billion to nine billion) and better living standards will lead to a big rise in energy consumption.

No single technology will fulfil this demand

Fossil fuel

- 80% of the developed world's energy
- Constrains in future decades

Nuclear Fission

- Growth may be limited by supply of uranium
- Public and political acceptability

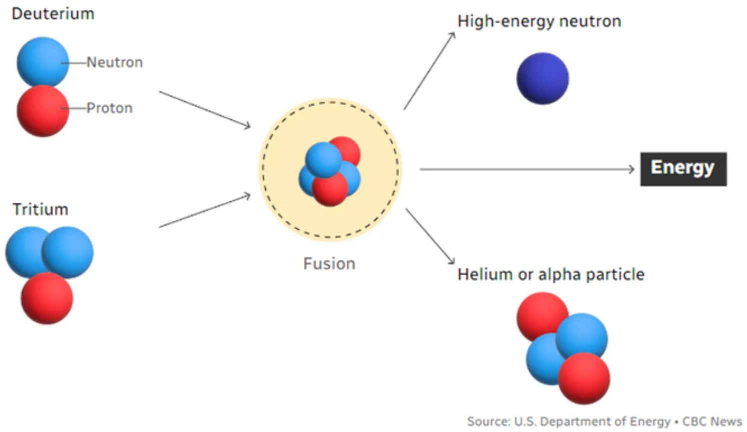
Renewable Energy

- Reliant on environmental conditions and transient in nature
- Technology challenges- large scale energy storage

Nuclear Fusion

- Abundant source of supply for 1000s of years
- No greenhouse gases
- Less long-lived radioactive waste and inherent safety features

Advantages of Fusion Energy



‘Create the power of the sun in a bottle here on earth’

The fusion reaction creates Helium and very high energy neutrons. These neutrons are the source of heat needed to create electrical energy.

Clean

- Zero Carbon emissions
- Fuel sourcing has negligible environmental impact

Energy Security

- Fuel is abundant and quite evenly distributed on Earth
- Minimal fuel challenges

Reliable

- Minimal fuel constraints / supply chain challenges
- Stable, uninterrupted baseload power

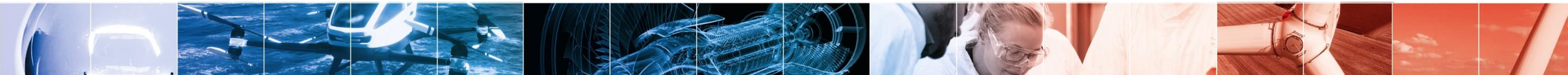
Scalable

- Risk appropriate regulatory burden or export controls
- Minimal land use or separation from social infrastructure

Safety Advantaged

- Meltdown not possible
- No long term, high-level radioactive waste
- No fissile materials like uranium and plutonium present
- Very low non-proliferation risk

Fusion could generate four times more energy per kilogram of fuel than fission (used in nuclear power plants) and nearly four million times more energy than burning oil or coal

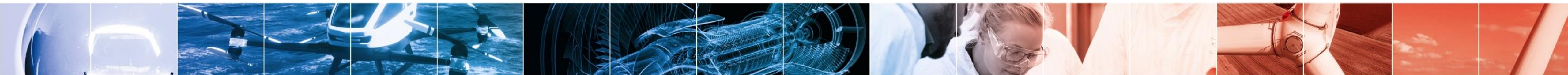


Challenges to Commercializing Fusion Energy

Key areas of focus for researchers to overcome the intricate engineering obstacles to commercialising fusion energy

NCC CMCs SiC/SiC

Technical Challenge	Research Focus
Material Science	Investigating new materials with superior heat and neutron-induced damage resistance, and assessing structural integrity under harsh radiation conditions
Robotic Maintenance	Maintaining the reactor entirely with robotics and remote maintenance techniques
Plasma Exhaust	Designing an exhaust system to deal with the intense heat from the plasm
Plasma Science	Confining fusion fuel in a plasma at temperatures ten time hotter than the sun’s core
Innovative Engineering	Taking advantage of new engineering and manufacturing techniques to advance fusion development
Fuel Handling	Breeding and handling tritium fuel to power commercial fusion machines

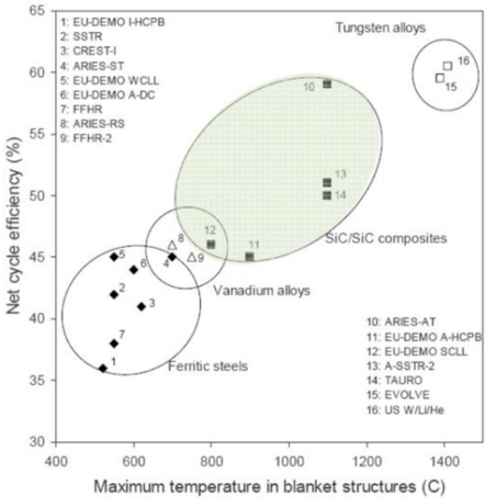


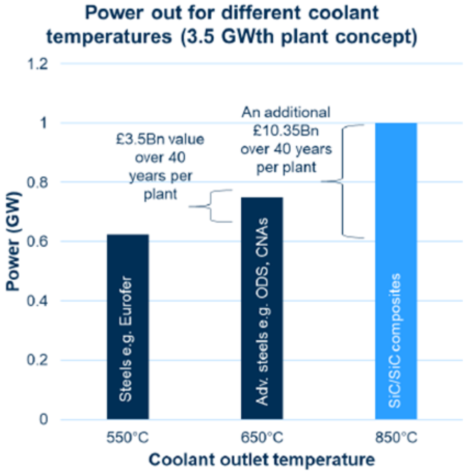
Bristol Composites Institute

Suitability of SiC/SiC for Fusion Energy

SiC/SiC is a promising material for fusion energy applications, particularly components for the plasma-facing and structural elements of a fusion reactor

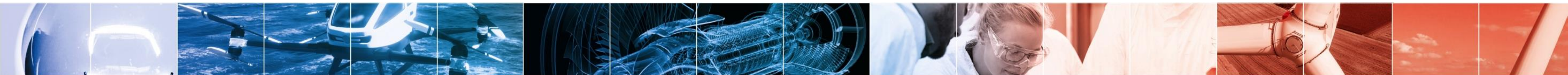
High-temperature resistance	Thermal stability up to 1600ºC
Radiation resistance	Long term use in fusion reactors
Low Neutron activation	Less radioactive waste
High strength and stiffness	Structural integrity
Thermal conductivity	Dissipate heat efficiently
Compatibility with tritium	It does not hinder fuel cycle



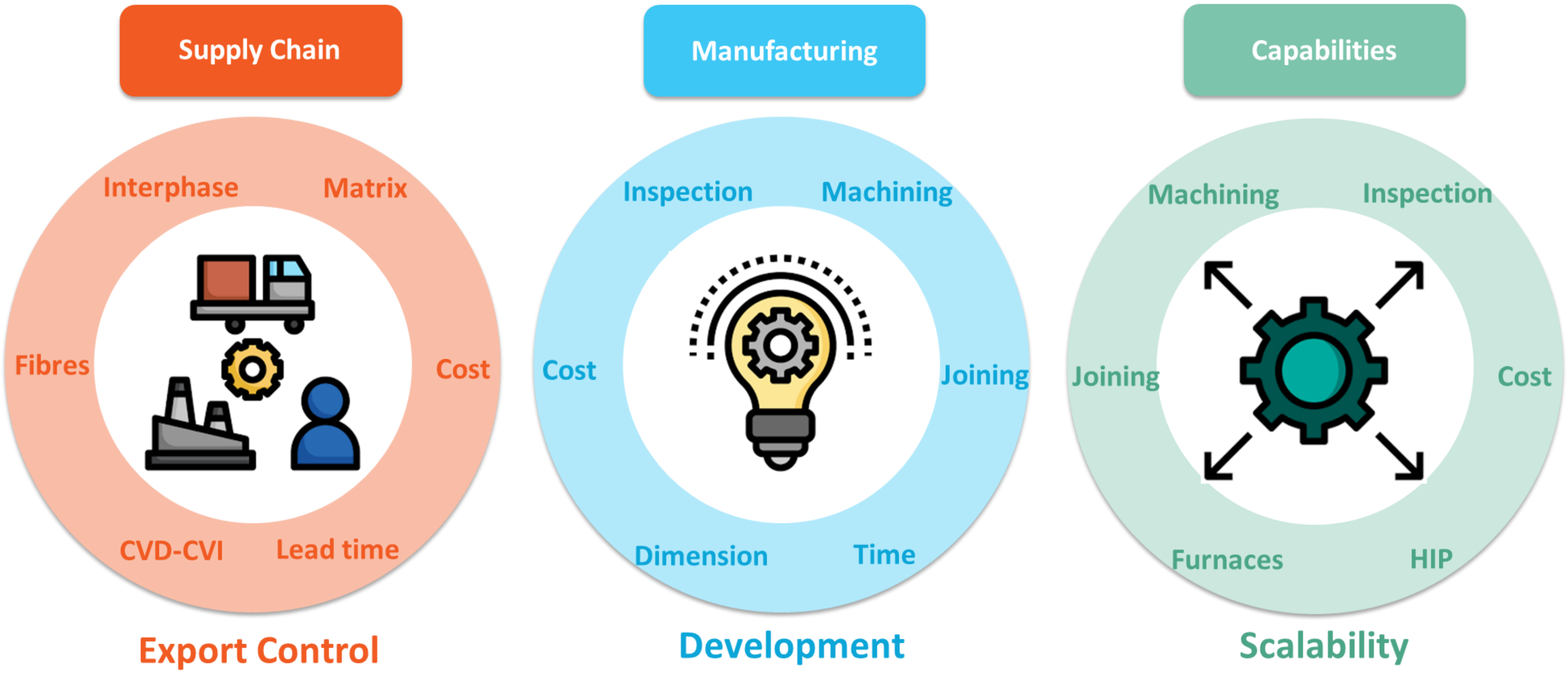


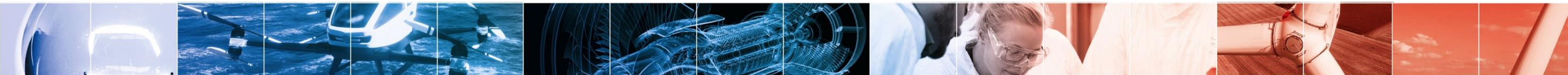
Higher operating temperatures allow higher coolant-outlet temperatures (up to 1100° C)

Research and development efforts are essential to address manufacturing challenges and optimise SiC/SiC performance



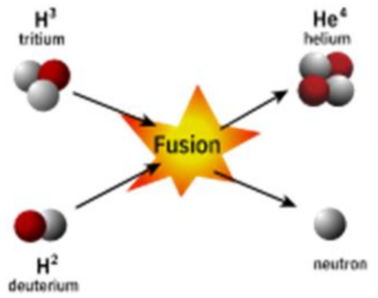
Analysis of Challenges to Manufacture SiC/SiC

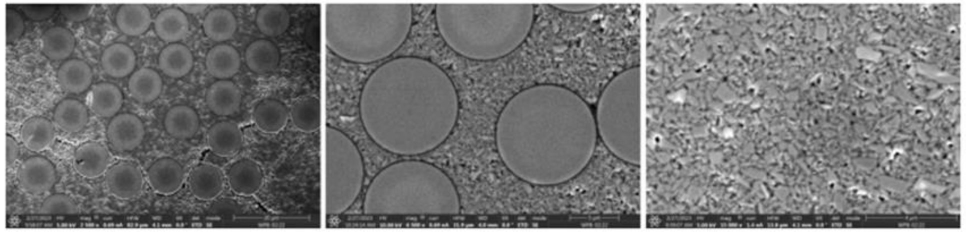




SiC-SiC Manufacturing

SiC-SiC CMCs have the potential to make nuclear fusion a reality. However, the CVI process currently used to manufacture SiC-SiC is expensive, time intensive and does not scale for large users of the material (e.g. AEA)





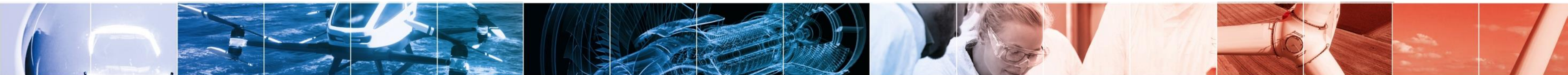
NCC have worked with partners at the University of Birmingham and AEA, to demonstrate the upscaling of a novel alternative process.

Manufactured parts have the desirable, dense microstructure containing closely-packed powder particles

Ongoing testing and characterisation is looking very promising

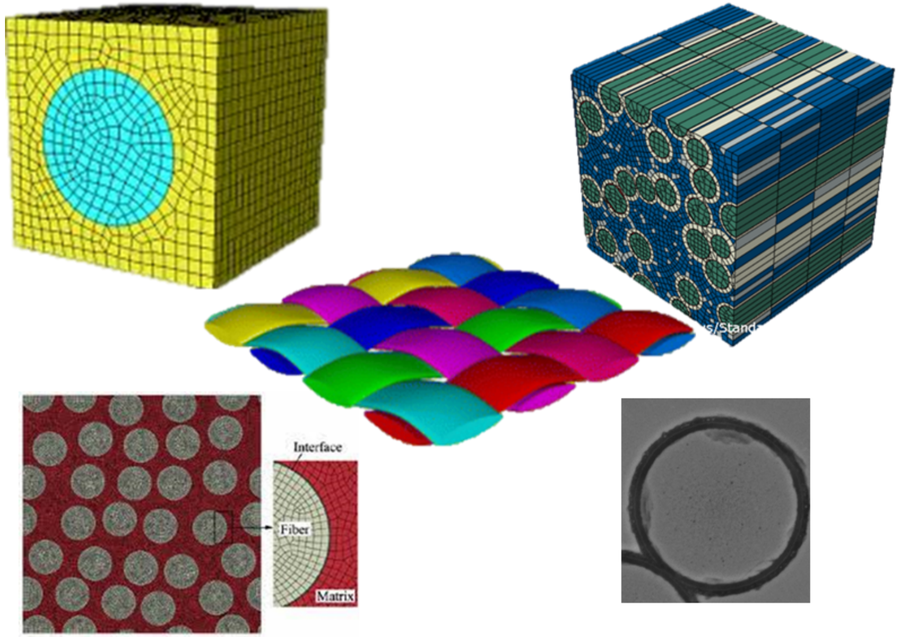
Process patent being explored to protect for UK benefit

The NCC has demonstrated a novel manufacturing process with potential to reduce cost by >80%, and cycle times by >50%, unlocking many potential future applications and projects.



SiC-SiC Modelling

Design of SiC-SiC is expensive and complex behaviours are currently hard to replicate. Rapid prototyping is not feasible therefore modelling capability is required to accelerate the develop to keep pace with wider industry development.



MultiTool Representative Volume element (RVE) model developed with BCI to fast-track development

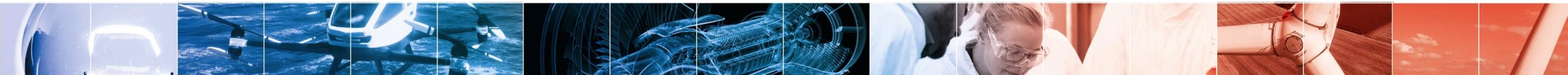
3-Stage analysis:

Micro-scale single-fibre -> Multi-fibre -> Mesoscale (Woven)

Enable design and structural analysis under irradiation of >1500°C

Able to modify parameters such as voids, interface thickness, mesh size and more making it a highly effective tool

Our AEA collaboration on this project enabled the Royce grant funded SiC-SiC manufacturing work a step change in cost and time



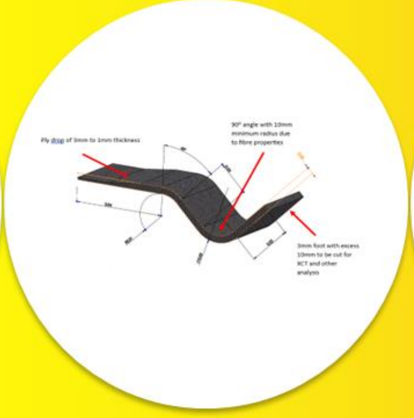
SiC-SiC Roadmap

Our vision is contributing to the materials, supply chain and capabilities development in UK. Adapt the knowledge and experience in OMCs to CMCs to push them to the industrialisation level

Current year

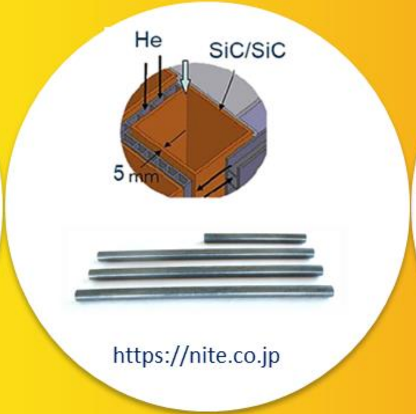
Flat panels
Mechanical, thermal, radiation tests

2 years



Semi-complex shapes

3 years



Complex shapes

5 years

Scalability

10 years

Joining complex demonstrator

Conclusion

- A new large-scale, sustainable and carbon-free form of energy is urgently needed. Fusion offers a long-term energy source that uses abundant fuel supplies and does not produce greenhouse gases or long-lived radioactive waste

- The extreme environment within a fusion reactor require development of materials to withstand these conditions

- SiC/SiC is a promising material due to its high-temperature and radiation resistance, low neutron activation, and mechanical strength

- An immature supply chain and lack in capabilities in UK for the manufacture of CMCs components must be addressed to respond to the future demand of these materials and help fusion energy to be a reality

- NCC has developed a new manufacturing process which cuts costs by 80% relative to the status quo, and has identified important challenges for SiC/SiC scalability