HENRY ROYCE INSTITUTE

ADVANCED MATERIALS RESEARCH & INNOVATION

UK FUSION MATERIALS ROADMAP 2021-2040

A call to arms – the age of fusion engineering and delivery has begun

CONTEXT

This year the UK selects the site for its very first fusion powerplant, the Spherical Tokamak for Energy Production (STEP), which will be the country's primary route to commercial power from fusion technology. The plant needs to be operational by the early 2040s so time is of the essence, not least in terms of recognising the materials research required to reach that point and beyond, making fusion a commercial reality.

Crucially this research can, at the same time, be linked to new ways of developing and evaluating materials through rapid develop, characterise and test methodologies, linking advanced experiments and modelling capabilities. There are fantastic opportunities for the wider UK materials community and manufacturing base to be engaged, and gain reward, from successful delivery of fusion power onto the national grid.

The challenge is large however. The fusion reactor environment is one of the most extreme environments any material will face, with the combination of high energy irradiation and thermal, magnetic, electric and mechanical loads. As such materials scientists need to seek creative new ways to demonstrate the viability of materials which will offer engineering assurance.

In this context, during 2021 the UK Atomic Energy Authority - with the support of The Henry Royce Institute – hosted a series of workshops with academia, industry and other bodies in order to produce a fusion materials roadmap presenting clear ideas for immediate R&D to close already defined fusion materials performance gaps. The roadmap also sought to suggest broader and more generic long-term materials improvements which could steer future engineering design in fusion tokamaks.

The resulting document is a call to arms for the UK materials community. Where there are opportunities to collaborate internationally, national and overseas capabilities should be linked to support the ambition. Where challenges are generic the roadmap invites involvement to shape research investment and planning in more depth.
And where next steps are outlined in detail, there is an invitation to create consortiums, seek funding, and deliver solutions.

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A MODERN MATERIALS APPROACH

Can we design materials that develop enhanced performance under irradiation conditions? How do we make fusion materials more sustainable? And can we design SMART materials for future powerplant operations? These are just some of the key questions that need to start being answered now if the UK is to make fusion a reality in the near future.

There is also a huge need to invest in facilities to test materials that have been irradiated. For instance more and better datasets are required on neutron cross-sections, decay heat, uncertainty quantification and neutronics benchmarks. Modellers in fusion will increasingly link reactor environment to materials behaviour, simulating materials responses in situ and taking account of local stress loading. This approach requires materials experiments linking loads, temperature and irradiation dose to provide data to underpin and validate the simulations.

Materials performance data will also play a key part in the increasing adoption of digital technologies in the design, monitoring, maintenance and repair of reactors and plants. Initially low-fidelity computational models will be required, but in time 'Design by Rule' (using handbooks of materials property data) will give way to 'Design by Fundamentals' which will harness more holistic representations of materials performance in context.

A WAY FORWARD – FUSION MATERIALS STEERING GROUP

The UK has a unique opportunity to capitalise on its world-leading position in fusion, most recently demonstrated by General Fusion's decision to build its demonstration facility at Culham, Oxfordshire. With consistent, long-term, dedicated funding, strategic partnerships can be built and a programmatic approach enacted to ensure robust and coherent R&D delivery.

It is now essential that a strong and diverse fusion materials supply chain is established. The UK has a wealth of knowledge from fission plant design and operation and there is a need to work collaboratively to define materials requirements. This should also be developed in unison with the Gen-IV design community as many material performance demands are shared with fusion materials.

This roadmap has identified a key community of individuals well-placed to advise and shape a materials research agenda with strong links to industries such as fission, oil and gas and aerospace. As such the Royce believes the creation of a Fusion Materials Steering Group would also now be beneficial as a sounding board for research proposals and to advise on overall direction and appropriate cross-cutting linkages.

If you would like to hear more about the Steering Group and ways in which you may be able to get involved please contact andrew.bowfield@manchester.ac.uk at the Royce.

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