Structural materials in nuclear reactors

New nuclear reactor concepts promise more efficient fuel use and to reduce high-level nuclear waste, while structural demands on materials become more stringent. Professor James Marrow's research improves methods for measuring the damage and longevity of materials.

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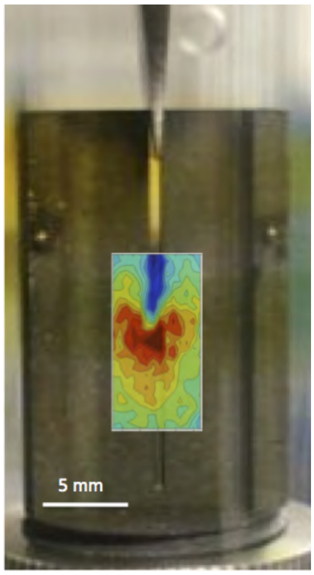
With increasing world energy demands and climate change, there is pressure to develop sustainable energy technologies. Nuclear energy can contribute; in 2013 Nuclear fission provided 11.7% of the worlds electricity, behind hydro power (16.3%) but well ahead of all other low carbon sources. However, although light water reactor (LWR) nuclear fission is broadly a low-carbon technology, breakthrough technologies are needed now to secure the long-term future of nuclear power. Fast neutron reactors with closed fuel cycles can reduce levels of high-level waste and contribute to more efficient use of uranium resources, which will be under pressure with an expansion of the LWR fleet. Certain fast reactor concepts have process heat applications, which can support economical hydrogen or synthetic hydrocarbon fuel production. The advanced nuclear fission plant concepts are referred to as "Generation IV" systems, and are intended to be in operation as commercial plant by the middle of the 21st Century.

The operating conditions of the Generation IV concepts will place significant demands on their structural materials, far more stringent than those for existing nuclear plant. In the longer term, nuclear fusion offers sustainable energy production without the issues of long-lived radioactive waste and nuclear proliferation that accompany fission; however, there remain very significant engineering challenges to be overcome. For the lifetimes of current reactors to be safely extended and also to inform the materials selection and design of future reactors, understanding of the mechanisms of deformation and damage are of great importance.

Professor James Marrow's research into this area is directed towards improving methods for measuring damage in the microstructure of materials, using three-dimensional imaging to validate and develop predictive models. Focussing on graphite, the material used to moderate neutrons in gas-cooled reactors, Professor Marrow has examined the formation and propagation of microscale cracks which may shorten the lifetime of the material, providing data to inform modelling on the engineering scale. This information is being used, in conjunction with both industrial partners and industry regulators, to better understand the structural integrity of nuclear components. His approach is now finding further applications in new materials, such as ceramic composites, that will be needed in future nuclear fission and fusion reactors. The analysis is extendable to a wide range of materials, including bone and bone replacements and composite materials for energy efficient transportation.



Oxford is uniquely placed to lead research in this field due to the availability of a wide variety of experimental techniques across several departments. Research at Oxford also benefits from close collaborations with the Diamond Light Source synchrotron facility and researchers within Europe engaged in the development of structural materials for nuclear fusion and fission power.

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