3 Coating Technologies

NEW COAT FOR HOT TILES

Plasma facing components in ITER have to survive intense thermal loads. The Fusion Association Euratom-MEdC from Romania has developed and industrialised a tungsten coating technology that can take the 'heat' and shows good signs of application in other industrial sectors.

Tungsten technique

The plasma temperature in a fusion reactor is in the range 50 – 100 million °C. Under these conditions, the first wall of the reactor chamber is subjected to an intense thermal loading with some areas of the plasma-facing wall reaching 2000 °C or more. There are not too many materials that can take this heat. One of them is carbon, particularly CFC (Carbon Fibre Composite), and another is tungsten (W). Both of these materials have advantages and disadvantages, but a combination of W coating on CFC material is a good solution from many points of view including cost.

Currently, the primary materials choice for ITER is a full beryllium main wall with CFC materials at the strike points and tungsten at the divertor baffles and dome. Since this combination has never been tested in a 'live' reactor, an ITER-like Wall project has been launched at JET in Culham, UK to test the new wall design. Combined Magnetron Sputtering and Ion Implantation (CMSII) technology, developed by the Association Euratom - MEdC in Romania, has been chosen as the best coating technique in terms of resistance to high heat fluxes (HHF) and will be used to provide a 10 micron (μm) W coating of around 1000 tiles for the new JET wall.

Industrial-scale

The transition of this technology from laboratory to industrial scale was a big challenge for MEdC. The small-scale laboratory coating unit measuring 300mm diameter by 420mm high was equipped with one magnetron with a maximum power of 800 W. For industrial scale coating, a chamber of 800mm diameter and 750mm height with 24 magnetrons and a corresponding higher power supply of 25 kW were necessary. Such equipment could provide the desired coating productivity of around 1 m2/week and accommodate tiles with a length up to 370mm. Two options were analyzed: the first being direct transfer of the technology to a SME and the second being the development of the technology to industrial scale in the National Institute for Laser, Plasma and Radiation Physics (NILPRP-MEdC).

Taking into account the lack of knowledge on the design and technological aspects of the industrial unit, as well as the short time available and limited financial resources, the second option was chosen led by the Plasma Surface Engineering Laboratory (PSEL) at MEdC. Following initial experiments the mechanical equipment was manufactured by SC Nuclear & Vacuum SA, a Romanian Company specialized in vacuum techniques with the electrical equipment designed and manufactured by PSEL. The software program was developed by a specialized Romanian Company, SC Inter-net SRL. By the end of 2007, within two years of the initial commissioning, the CMSII industrial coating unit was installed and and ready for use.

Thermal expansion

A major issue with W coatings on CFC tiles is the anisotropic thermal expansion of the bidirectional fibre-reinforced CFC. This was overcome by the deposition of an intermediate molybdenum (Mo) layer of 2 – 3 μm which compensated for the thermal expansion mismatch. The qualification of the CMSII technology was based on the results of High Heat Flux tests using the GLADIS hydrogen beam facility at IPP Garching. Testing up to 2000 °C has taken place without delamination of tile coatings.

Application

More than 200 CFC tiles have already been coated for JET after successful tests on prototypes at the Association Euratom - IPP Garching in Germany. The same coating technology is being used for almost 300 plasma facing components made of Fine Grain Graphite (FGG) and CFC for the ASDEX Upgrade tokamak at IPP Garching. Intensive research is carried out with the aim to produce by the same technique, on some particular CFC tiles, W coatings with a thickness of 20-25 µm.

CMSII is a very versatile thin coating, competitive technology, which can also be successfully applied in other sectors such as cutting tools, forming and forging tools, amongst other applications. The Association Euratom - MEdC is now enquiring on further exploitation of this technology with potentially interested parties.

The Partners

Euratom Associations:

Association Euratom – MEdC National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania
Association Euratom – IPP, Max-Planck Institut für Plasmaphysik, Garching, Germany
Association Euratom - UKAEA, Culham Science Centre, UK

Industry Partners:

SC Nuclear & Vacuum SA, Romania
SC Inter-net SRL, Romania

A reference price for 10 µm W coating of carbon based materials (CFC or FGG) is 8,500 EUR/ m2, but this depends on the geometry and number of tiles.

C. Ruset, NILPRP, Romania