Porous silicon carbide with tailored thermal and electrical properties

CEIT, a research center located in San Sebastian (Spain) has developed a method for producing porous SiC with tailored porosity and thus, controlled thermal and electrical properties. It was developed for fusion application as Flow Channel Inserts in high temperature Dual-Coolant Lead-Lithium (DCLL) blankets, where it served as electrical and thermal insulator. Hollow channels of complex geometries were produced and tested under a PbLi flow at 700°C. Based on gelcasting route, this know-how offers a low cost technique which is industrially scalable and allows consolidating complex shapes with high green strength. It avoids the end-capping defects that usually appear in ceramics samples produced by uniaxial pressing. This material could find application in other fields outside fusion such as filters for molten metal or high-temperature gas, volumetric absorbers of solar radiation, separation membranes, high temperature structural materials, among others.

Description of the technology

A method for producing porous SiC with tailored porosity and thus, controlled thermal and electrical properties, has been developed at CEIT. Porous SiC samples were fabricated and characterized by this method, based on the sacrificial template technique and using graphite spherical powder as the sacrificial phase. Materials with a wide range of properties were obtained, being the most interesting those with a porosity in the range of 45-50%, presenting a thermal conductivity of ~11 W/(m·K) and a mechanical strength of 107 Mpa. They have been produced for application as Flow Channel Inserts (FCI) in a high-temperature Dual-Coolant Lead-Lithium (DCLL) blanket. A typical microstructure is shown in Figure 1. The electrical conductivity of these materials is well below 10^{-1} S/m in the temperature range RT – 700°C, which is a good value for FCI application. In this application, porous SiC acts as thermal and electrical insulator to decouple thermally and electrically a flow of liquid lead-lithium alloy (Pb16Li) at to 700°C from the cooled steel structure, whose maximum allowable temperature is 470°C.

To fabricate porous SiC hollow channels, the gelcasting route was used. Different geometries with 25 x 25 mm^2 section and ~5 mm thickness were successfully produced, as can be seen in Figure 2: long channels of ~110 mm length, stepped hollow channels to be assembled in sets of three channels to form a duct 120 mm long, and 90° corner hollow channels in one piece without defects. These channels have been exposed to experiments under a flow of liquid lead-lithium alloy up to 700°C during period of up to 30 days, to simulate the conditions expected at FCIs in a high temperature DCLL blanket.

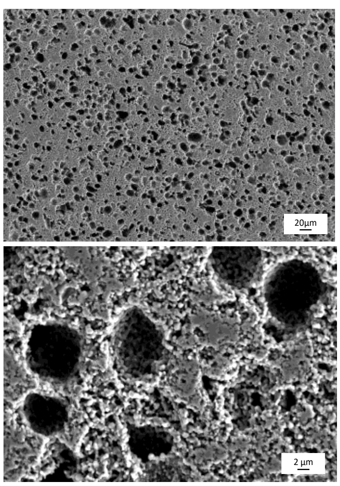

Figure 1. Microstructure of porous SiC pieces produced by gelcasting.

Figure 2. Porous-SiC lab-scale FCI prototypes produced by gel casting.

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Innovation and advantages of the offer

Hollow pieces of complex geometry made of porous SiC ceramic with tailored porosity and thus, controlled thermal, mechanical and electrical properties can be fabricated with the proposed technology. The sacrificial template method is used for producing porous SiC with controlled porosity using graphite spherical powder as the sacrificial phase. The gelcasting route is used for fabricating hollow pieces. This route offers advantages over conventional consolidation techniques since it is a relatively low cost technique industrially scalable that allows consolidating complex shapes with high green strength avoiding the end-capping defects that usually appear in ceramics samples produced by uniaxial pressing.

Non-fusion Applications

Porous SiC ceramics exhibit a unique combination of properties: high temperature strength, high chemical stability and corrosion resistance, high thermal shock resistance, outstanding oxidation resistance, light weight, low thermal expansion coefficient. Porous SiC can be used in catalyst supports, filters for molten metal or high-temperature gas, volumetric absorbers of solar radiation, separation membranes, acoustic and thermal insulators, high-temperature structural materials, thermoelectric energy conversion, water filtration, porous burners, diesel particulate filters with honeycomb structures, high-temperature/high-voltage semiconductor electronics, etc.

EUROfusion Heritage

CEIT has developed porous SiC materials for Flow Channel Inserts in high temperature DCLL blankets. This material has been developed within two Enabling Research projects belonging to the EUROfusion program: ENR-MFE15.CIEMAT-09-T001-D004 (2015-2017) and ENR-MFE19.16-CEIT-01-T002-D001 (2018-2020). A method to produce porous SiC with tailored porosity and, thus, controlled thermal and electrical properties, has been developed. Different geometries of porous SiC hollow channels were successfully produced by the gelcasting method.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Annex for internal use – Additional information

Technology Provider

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Technology Readiness Level and collaboration opportunities

☐ TRL1 ☐ TRL2 ☐ TRL3 ☒ TRL4 ☐ TRL5 ☐ TRL6 ☐ TRL7 ☐ TRL8 ☐ TRL9

It has been made small prototypes at laboratory scale.

Collaboration opportunities: Subcontracting or a collaboration contract in a project with other actors through the knowledge.

IP Status

- ☐ Copyright
- ☐ Design Rights
- ☐ Exclusive Rights
- ☐ Granted patent or patent application essential
- ☐ Other (registered design, plant variety, etc.)
- ☐ Patent(s) applied for but not yet granted
- ☐ Patents granted
- ☒ Secret Know-how
- ☐ Trademarks

Other technical expertise's of the technology donor

Materials for nuclear fusion applications and plasma-wall interaction in fusion devices: oxidation-resistant tungsten alloys, SiC-based materials, ODS steels and doped carbon-based materials, using mainly powder metallurgical routes

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