Deuterium Retention in Silicon Carbide Materials

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Introduction

• Silicon Carbide (SiC) can be used in high temperature, corrosive environments due to its high melting point and chemical stability
• SiC as a "low-Z" material can be tolerated in higher concentrations as fusion plasma impurity than e.g. metallic impurities
• Disadvantages are the low mechanical shock tolerance and the poor manufacturability of 3D structures
• Ceramic Matrix Composite (CMC) of SiC could overcome these issues
• Concepts to use SiC composites as a structural material for the ARIES-AT power core [1]
• Erosion yield, and codestination properties of SiC well researched, however little data on deuterium retention especially for composite materials
• The objective of this work thus is to characterise and compare the deuterium retention properties in bulk SiC, SiC/SiC, C₁₋₃SiC and SiC coated graphite

Experimental Methods

Results and Discussion

• The shape of selected TDS curves is depicted in Fig. 1 with curves from the literature [2, 3]
• Variance in main peak position most likely result of different temperature measurement approaches
• Overall shape with dominant major peak (Si-D) and minor or missing secondary peak (C-D) at higher temperatures
• Shape and amount of retention in SiC/SiC and SiC coated graphite similar to bulk SiC, C₁₋₃SiC rather to graphite

Table 1: Origin and properties of the tested materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Origin</th>
<th>Type</th>
<th>Density</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>Ottech Ceramics</td>
<td>Stuttgart</td>
<td>-</td>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>SiC/SiC</td>
<td>DLR Stuttgart</td>
<td>-</td>
<td>1.45</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C₁₋₃SiC</td>
<td>General Atomics</td>
<td>San Diego</td>
<td>.45</td>
<td>2.2</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 1: Thermal desorption spectroscopy profiles
- The trend lines reveal an almost linear decrease in the magnitude of retained deuterium with increasing temperatures
- Bulk SiC and SiC/SiC show quite similar retention curves

Figure 2: Fluence dependent deuterium retention
- SiC coated graphite shows quite similar retention curves compared to SiC/SiC and SiC/SiC coated graphite curve
- The last two data points of the SiC coated specimen are rather low in magnitude. The magnitude of the non-linear decrease might be flawed and should be verified by further experiments

Conclusion

• The total amount of retained deuterium is similar for all investigated materials with a significant silicon content at the surface (bulk SiC, SiC/SiC, SiC coated graphite)
• Neither the fibres nor the porosities seem to foster retention
• The difference in the amount of deuterium retention between graphite and the tested SiC materials decreases with increasing specimen temperature indicating that thermonuclear devices operated at high wall temperatures will only face moderate increases in retention if the walls are changed from graphite to SiC materials
• If a small increase in the hydrogenic retention can be tolerated, SiC CMC materials could be an alternative to graphite as a structural material in fusion devices to benefit from the superior mechanical properties

References


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