SiC/C components for nuclear applications from low cost precursor

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SiC for nuclear applications

• Key problem: suitable material facing plasma (first wall and breeder blanket of the reactor)

• SiC greatest potential:
  – Low afterheat
  – Low nuclear activation energy
  – High resistance to radiation damages
  – Excellent dimensional stability at high temperature
Our laboratory

- Manufacture of several types of SiC composites (whiskers, monoliths) with different properties:

  - **SiC Whiskers**: 8 GPa
  - **Biomorphic SiC**: Porosity: 20-60% BS: 50-200MPa
  - **SiC/MeSi₂**: BS: 400MPa
  - **SiC/C**: BS: 150-300MPa
Our laboratory

• Study of the interactions of liquid metal with SiC and carbon materials:
Advantage

• By economically viable route:
  – Reactive infiltration process:
    • Low synthesis T (~ 1450°C)
    • Short processing time
    • Atmospheric pressure
    • Near net shape
How is this possible?

• Manufacturing SiC materials with different microstructures by control of the Si-C chemical reaction
  – Optimization of the carbon substrate microstructure:
    • Appropriate carbon precursor
    • Right thermal treatment

• Increase viability: low cost precursor
  – Rice husk
  – Wood, sawdust
  – Graphite
High temperature treatment affects the microstructure

BioSiCSw-1400

BioSiCSw-2500
Achievement

• Development of self-sintering carbon substrates with tailor-made microstructure from petroleum residues:
  – Low cost material
  – No binder addition
  – Control of self-sintering
  – Control of porosity
  – Control of microstructural development
Feedstocks

- Crude Oil
- Atmospheric Distillation
- Catalytic Reformer
- Vacuum Distillation
- Fluid Catalytic Cracking
- Heavy Vacuum Gas-Oil
- Vacuum Residue (VR)
- Decanted Oil (DO)
- Ethylene Tar (PY)

Naphtas

Reformate

- Naphta
Experiemental Procedure

1. **Feedstock**
2. **PYROLYYSIS**
   - Semicoke preform
   - Conditions: 1400°C, 60min, Ar
3. **CARBONIZATION**
   - Semicoke preform
   - Conditions: 1400°C, 60min, Ar
4. **MILLING**
   - Semicoke particles
   - dp: < 63 μm
5. **SIEVING**
   - Semicoke particles
   - dp: < 63 μm
6. **PRESSING**
   - Semicoke particles
    - Conditions: 1450°C, 60min, Ar
7. **INfiltration Si**
   - Porous carbon preform
   - SiC monoliths from carbonized preforms
**Semicokes**

**VR: Vacuum Residue**
- Lower aromaticity
- High ramified hydrocarbons

**PY: Polyethylene Tar**
- Most aromatic

**DO: Decanted Oil**
- Intermediate aromaticity
- H donors

**Images:**
- VR-460-3: Mosaic
- PY-480-5: Flow Anisotropy
- DO-480-6: Flow domains
Reactivity with Si

PREPARATION OF POWDER MIXTURE

Semicoke particles + Silicon particles → MIXING → Particles mixture

REACTION

Reaction Conditions
a) 1350°C, 180 min
b) 1400°C, 60 min
c) 1400°C, 180 min

SiC + Si + C mixture

DETERMINATION OF UNREACTED CARBON

SiC + Si + C Mixture → O₂, 800°C, 12 h → SiC + Si mixture

DETERMINATION OF UNREACTED SILICON

HF/HNO₃ → SiC particles
• Reaction in powder state

<table>
<thead>
<tr>
<th>Treatment</th>
<th>SiC Yield (%)</th>
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<tbody>
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<td>a) 1350°C, 180 min</td>
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<tr>
<td>b) 1400°C, 60 min</td>
<td>80</td>
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<td>c) 1400°C, 180 min</td>
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SiC yield
## Porous carbon preforms

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<th>Sample</th>
<th>Pyrolysis</th>
<th>Pressing</th>
<th>Preforms 1400°C</th>
<th>SiC components</th>
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<td>T (°C)</td>
<td>t (h)</td>
<td>P (MPa)</td>
<td>ρ_a (g/cm³)</td>
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*Incomplete infiltration

**Minimum porosity for infiltration: 36%**
## Effect of carbon type

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<td>t (h)</td>
<td>P (MPa)</td>
<td>ρ_a (g/cm³)</td>
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<td>40</td>
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### Mechanical properties

![Graph showing the relationship between SiC density (g/cm³) and BS (MPa) for samples VR, PY, and DO.](image)

- BS (MPa) on the y-axis ranges from 0 to 450.
- SiC density (g/cm³) on the x-axis ranges from 2.2 to 3.0.
- The graph includes data points for VR, PY, and DO samples.
- A dashed red line indicates the trend in the data.
No residual Si

Residual coke particles
Pores
SiC

Absence of residual Si
Graphitization

**DRX**

**Reactivity with Si**

![Graph showing DRX patterns and reactivity with Si]

- **Intensities (cps)**: DO-480-6, PY-2500, DO-2500, PY-1400, DO-1400, PY-480-5, DO-480-6
- **2θ (degrees)**: 20 to 50

**SiC yield (%)**

- **VR**: a) 1350ºC, 180 min
- **PY**: b) 1400ºC, 60 min
- **DO**: c) 1400ºC, 180 min
  g) 1400ºC, 180 min
Graphitization

Mechanical properties

![Graphitization Image](image)

**DOG-480-6-20**

**PYG-480-5-160**

**DOG-480-6-20**

**PYG**

**VR**

**DO**

**BS (MPa)**

![Graphitization Graph](image)

**SiC_{comp} Density (g/cm³)**

**NIMA INSTITUTO UNIVERSITARIO DE MATERIALES DE ALICANTE**
• A wide range of carbon preforms were conformed from different semicokes without addition of binder.

• Carbon preforms with porosity above 36% were completely infiltrated.

• Degree of conversion of carbon into SiC depends on the reactivity of the carbon substrate.

• More ordered carbon substrate, more reactive with silicon.

• SiC components with 287MPa of bending strength were produced from PYG. Twice the BS of commercially available RBSC.

• Suitable for applications at T > 1200ºC (no residual silicon)
Acknowledgements

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Thanks for your attention!!!
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