CMAS Ingression Study on EB-PVD Thermal Barrier Coatings using Synchrotron X-Ray Diffraction

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Motivation and Objective

**Motivation:**
- During CMAS ingestion, yttria is depleted
- Causes phase transformations within the coating
- Increases strain and risk of failure
- Decreases lifetime expectancy
- High-energy X-ray diffraction can quantify phases present

**Objective:**
- Determine the effect of CMAS ingestion on TBC by measuring the phase volume fraction (PVF) of the monochromatic phase (mPVF) present in the coating

2D XRD & Phase Volume Fraction Theory

- High-energy X-rays transmit through material, producing unique Debye-Scherrer rings according to the lattice translating of the present crystalline phases
- Rings hold information regarding the amount of phases present, texture, and strain within the material
- Phases can be identified through reference XRD databases

**Experimental Setup**

Sample Table: of samples used during this study with their parameters

<table>
<thead>
<tr>
<th>Label</th>
<th>Composition</th>
<th>Temperature (°C)</th>
<th>Total Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>Pure 7YSZ</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A2</td>
<td>Pure 7YSZ</td>
<td>1225</td>
<td>10</td>
</tr>
<tr>
<td>A3</td>
<td>Pure 7YSZ</td>
<td>1250</td>
<td>10</td>
</tr>
<tr>
<td>B2</td>
<td>7YSZ-CMAS</td>
<td>1250</td>
<td>1</td>
</tr>
<tr>
<td>B3</td>
<td>7YSZ-CMAS</td>
<td>1250</td>
<td>10</td>
</tr>
</tbody>
</table>

The chemical composition of CMAS by weight percentage

<table>
<thead>
<tr>
<th>Elements</th>
<th>SiO\textsubscript{2}</th>
<th>CaO</th>
<th>Al\textsubscript{2}O\textsubscript{3}</th>
<th>FeO</th>
<th>MgO</th>
<th>TiO\textsubscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt %</td>
<td>40</td>
<td>22</td>
<td>18</td>
<td>10</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

**Introduction**

- Thermal barrier coatings (TBCs) are applied to turbine blades to insulate superalloy blades in jet engines
- Yttria-stabilized zirconia (YSZ) is the standard material for TBCs
- Coating is applied through Electron-Beam Physical Vapor Deposition (EB-PVD) resulting in a columnar microstructure
- Deposits, such as sand or volcanic ash, enter the engine, melts and ingresses into the coating during operation \[1,2\]

**Conclusion**

- Depth of CMAS ingression can be quantified through mPVF
- CMAS has a significant effect on the amount of monochromatic phases present in the coating
- This effect can be seen throughout the depth of the coating
- mPVF decays exponentially throughout the depth of the coating
- Annealing time strongly affects the tetragonal to monochromatic phase transformation
- Longer annealing times result in higher monochromatic phase
- CMAS is able to ingress further into and react with the coating

**Future Work**

- How does the deposit ingestion effect the strain state of the coating
- How does annealing of the coating affect the strain state of the coating

Acknowledgements & References

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References: