Microstructure and hydrogen storage properties of FeTi + x wt.% Hf alloys (x = 0, 4, 8 and 12)

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1. State of art
   - Renewable energy
     - Hydrogen

2. Metal Hydride
   - FeTi alloy

3. Fe-Ti-Hf system
   - Microstructure
   - First hydrogenation properties

4. Conclusion
   - Outlook
   - Perspectives
Energy: big challenge of the XXI century

- High population growth
- Limited reserves of fossil fuel
- Reduction in emissions of greenhouse gases
- Renewable energy

HYDROGEN

- Urban transport
- Electronic
- «Stationary» application
Hydrogen storage

Hydrogen liquid
-253°C / 1 atm

Compressed
25°C / 350 to 700 atm

Metal hydride
25°C – 1 atm

Best way to store hydrogen
1. Adsorption (and dissociation) of hydrogen

2. Diffusion of hydrogen (absorption)

3. Total absorption of hydrogen in the material
FeTi alloy

Outline
State of art
Metal Hydride
Fe-Ti-Hf system
Conclusion

Space group Pm\bar{3}m

Well known as metal hydride
Reversible at RT
Low price
Low capacity (1.9 wt.%)
First hydrogenation
Alternative process

- Substitute Fe by Mn
- Add some dopants such as:
  - Zirconium (Zr),
  - Nickel (Ni),
  - Zr\(_7\)Ni\(_{10}\),
  - Hafnium (Hf)

Activation curves of FeTi and FeTi doped with Zr and Ni, at 25°C under 45 bar of H\(_2\).
Microstructure

- Matrix (A) + secondary phase (B)
- Presence of dendritic phase
Element mapping by EPMA

<table>
<thead>
<tr>
<th>Phase Composition</th>
<th>FeTi + 4wt.%Hf</th>
<th>FeTi + 8wt.%Hf</th>
<th>FeTi + 12wt.%Hf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix</td>
<td>48.9Fe – 49.0Ti – 1.9Hf</td>
<td>49.7Fe – 49.5Ti – 0.7Hf</td>
<td>49.3Fe – 49.7Ti – 1.0Hf</td>
</tr>
<tr>
<td>2nd phase (1)</td>
<td>53.2Fe – 40.3Ti – 6.4Hf</td>
<td>58.5Fe – 39.9Ti – 1.6Hf</td>
<td>56.7Fe – 40.4Ti – 2.8Hf</td>
</tr>
<tr>
<td>2nd phase (2)</td>
<td>34.5Fe – 59.8Ti – 4.7Hf</td>
<td>-</td>
<td>-</td>
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Activation properties

- Need a minimum of 8 wt.% of Hf to activate FeTi
- No incubation time
- Kinetic increases with wt.% Hf

<table>
<thead>
<tr>
<th>% Hf</th>
<th>4</th>
<th>8</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>% H abs.</td>
<td>0</td>
<td>1.1</td>
<td>1.4</td>
</tr>
</tbody>
</table>
Resume

- FeTi needs a minimum of \textbf{8wt.\% Hf} to be activated
  - Role of the Ti rich phase

- FeTi alloy doped with hafnium has a good industrial base
  - Low cost
  - First hydrogenation at room temperature
  - Fast kinetic

Perspective

- Identify the 2\textsuperscript{nd} phase by neutron diffraction
Thank you for your attention

Questions?