Amorphous iron-carbon nanoparticles with a size of 3 nm

T. Enz¹, S. Bhattacharya¹, B. Stahl¹, G. Miehe¹, H. Hahn¹, K. Foster², M. Winterer³

¹ Darmstadt University of Technology, Institute of Materials Science
² Forschungszentrum Karlsruhe GmbH, Institut für Nanotechnologie
³ Universität Duisburg-Essen, Institut für Verbrennung und Gasdynamik, Lehrstuhl für Nanopartikel-Prozeßtechnik

INSTITUTE OF MATERIALS SCIENCE - THIN FILMS DIVISION

**Chemical Vapor Synthesis (CVS) and Phase Analysis (XRD)**

- Pressure: 20 mbar
- Furnace temperature: 1000 - 1600 °C

Despite the drastic variations in furnace temperature and synthesis atmosphere there’s no change in phase composition but only in phase quantity.

**Moßbauer spectroscopy and comparison with literature data**

- Mößbauer spectra reveal the same phases as the XRD patterns
- The nanoparticles show superparamagnetic relaxation at room temperature, the blocking temperature is around 30 K
- Despite the drastic variations in furnace temperature and synthesis atmosphere there's no change in phase composition but only in phase quantity.

**Microcrystalline particles and carbon nanotubes**

- Single crystalline particles of either austenite or ferrite (not shown here) surrounded by graphite layers
- Indices and calculated spacings of the diffraction rings are in agreement with the sharp peaks in the XRD patterns
- Under certain conditions, the formation of multi-walled carbon nanotubes with large inner diameters as well as single-walled carbon nanotubes (not shown here) is observed

**Conclusions**

- Synthesis of amorphous Fe-C particles can be done with extremely low cooling rates (10⁴ K/s) due to the high carbon content
- The nanoparticles reveal a core-shell structure:
  - Core (Fe-C): amorphous iron
  - Shell: metallic state (no carbides or oxides)
  - Particle size
    - Carbon content
    - Amorphous phase
    - Cooling rate
  - By-products: single crystalline ferrite, austenite particles with graphite shells, nanotubes with large inner diameters

**Data table**

<table>
<thead>
<tr>
<th>nanoparticles</th>
<th>ferrite</th>
<th>austenite</th>
<th>graphite</th>
</tr>
</thead>
<tbody>
<tr>
<td>phase fraction (weight%)</td>
<td>60 - 97</td>
<td>2 - 8</td>
<td>1 - 5</td>
</tr>
</tbody>
</table>