Poster Session A: Synthesis
Poster Session A: Synthesis

76 papers!

Firstly: an overview......
Poster Session A:  Synthesis

Theory and Modelling  4

Measurement Development  4

Experimental  68
However, more synthesis in Poster Session B
Poster Session A: Synthesis

CVD

- Normal
- Plasma Enhanced
- Hot Wire
- Ultrasonic
**HYDROCARBON FEEDSTOCKS**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;5&lt;/sub&gt;OH</td>
<td>10</td>
</tr>
<tr>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
<td>8</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;4&lt;/sub&gt;</td>
<td>7</td>
</tr>
<tr>
<td>CO</td>
<td>6</td>
</tr>
<tr>
<td>C&lt;sub&gt;6&lt;/sub&gt;H&lt;sub&gt;14&lt;/sub&gt;</td>
<td>3</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;H&lt;sub&gt;6&lt;/sub&gt;</td>
<td>1</td>
</tr>
<tr>
<td>C&lt;sub&gt;10&lt;/sub&gt;H&lt;sub&gt;16&lt;/sub&gt;O</td>
<td>1 (Camphor)</td>
</tr>
</tbody>
</table>
Poster Session A: Synthesis

TUBE TYPES

Multi Wall 20
Single Wall 34
Double Wall 6
Poster Session A: Synthesis

Four THEORY / MODELLING PAPERS

A13/A14  Curtarolo et al  MD and physics melting, G-T eq

A52      Hirama et al    MD role of oxygen, stops shells

A56      Nasibulin et al Specific mechanism for tube formation. (penta/hepta gons)

A60      Bichara et al  MC carbon adsorbed at surfaces of Ni particles
Poster Session A: Synthesis

Technique development to improve understanding

A12  Svrcek et al  Growth on microbalance
A29  Hart and Slocum  Upthrust of growing carpet
A47  Chiashi et al  In situ Raman, incub. time
A48  Arcos et al  In situ PES, cat. ox. states
A65  Hart and Slocum  Combinatorial in microchannels

But no papers here on in-situ HR TEM?

Poster Session A: Synthesis

Experimental (a):
Control of SWNT diameter

A56 (e.g.) Nasibulin et al
Controlled by catalyst diameter

A23 Jeong et al
Catalyst diameter - no effect

A21 Inoue et al
Controlled by alloy elements in catalyst

A24 Saito et al
Controlled by composition of feedstock

Who is right? All? Visit these posters
Poster Session A: Synthesis

Experimental (b):
Some interesting chemical variants

<table>
<thead>
<tr>
<th>编号</th>
<th>作者</th>
<th>内容</th>
</tr>
</thead>
<tbody>
<tr>
<td>A37</td>
<td>Kumar et al</td>
<td>Camphor works v. well for MWNTs</td>
</tr>
<tr>
<td>A21</td>
<td>Inoue et al (again)</td>
<td>Subst. (+Co) of Rh &amp; Pd for Fe &amp; Ni</td>
</tr>
<tr>
<td>A9</td>
<td>Gruneis et al</td>
<td>$^{12}$C and $^{13}$C isotopes Affects diam. (9)</td>
</tr>
<tr>
<td>A11</td>
<td>Harutyunyan et al</td>
<td>Writing ‘bar code’ to follow growth (11)</td>
</tr>
<tr>
<td>A45</td>
<td>Ren et al</td>
<td>Sulphur affects kinetics, Shown to be in Fe/carbon interface (71)</td>
</tr>
<tr>
<td>A71</td>
<td>Motta et al</td>
<td></td>
</tr>
<tr>
<td>A23</td>
<td>Jeong et al (again)</td>
<td>Other metal containing proteins than ferritin</td>
</tr>
<tr>
<td>A24</td>
<td>Saito et al (again)</td>
<td>Metal-containing ‘reversed’ miscelles</td>
</tr>
<tr>
<td>A10</td>
<td>Esconjauregui et al</td>
<td>Non transition catalyst metals: Al, Na, Cs !</td>
</tr>
</tbody>
</table>
Experimental (b): Some interesting chemical variants

- Camphor works v. well for MWNTs
- Subst. (+Co) of Rh & Pd for Fe & Ni
- 12C and 13C isotopes affects diam. (9)
- Writing 'bar code' to follow growth (11)
- Sulphur affects kinetics, Shown to be in Fe/carbon interface (71)
- Other metal containing proteins than ferritin
- Metal-containing ‘reversed’ miscelles
- Non transition catalyst metals: Al, Na, Cs!

Can we find a few simple underlying principles?
Poster Session A: Synthesis

Experimental (c):
First stage assembly at synthesis

A01 Mueller et al
A38 Borrowiak-Palen et al
Filling MWNTs with Fe, Co, Ni (01) and SWNTs with Ag, Fe etc. (38) (n.b. posters (b)).

A05 Yoo et al
A57 Hayashi et al
Control and enhancement of vertical alignment from substrates.

A34 Ago et al
Horiz alignment on ‘A’ face sapphire

A68 Moisala et al
A70 Motta et al
Direct spinning of high performance fibres from CVD reaction.

A08 Na et al
A29 Hart and Slocum
Patterning of vertical growth (8), patterning into a micromould (29), on tips of Si nanostructures (39)

A39 Weng et al
Experimental (c):
First stage assembly of synthesis

A01 Mueller et al
Filling of MWNTs with Fe, Co, Ni (01) and SWNTs with Ag, Fe etc. (38) (n.b. posters (b).

A38 Borrowiak-Palen et al
Control and enhancement of vertical alignment from substrates.

A05 Yoo et al
Horiz alignment on ‘A’ face sapphire

A57 Hayashi et al
Direct spinning of high performance fibres from CVD reaction.

A34 Ago et al
Patterning of vertical growth (8), patterning into a micromould (29),

A68 Moisala et al
on tips of Si nanostructures (39)
Poster Session A: Synthesis

Process Variables:
example of floating catalyst

1. Reaction vessel temperature
2. Reaction vessel design
3. Carrier gas composition
4. Carrier gas flow rate
5. Type of feedstock
   (ethanol, hexane, acetone, ethylene glycol,....)
4. Rate of injection of feedstock
5. Composition of catalyst and precursor type
6. Rate of injection of catalyst
7. Rate of removal of carbon nanotubes (if at all)
Poster Session A: Synthesis

Process Variables:
example of floating catalyst

1. Reaction vessel temperature
2. Reaction vessel design
3. Carrier gas composition
4. Carrier gas flow rate
5. Type of feedstock (ethanol, hexane, acetone, ethylene glycol,...)
6. Rate of injection of feedstock
7. Composition of catalyst and precursor type
8. Rate of injection of catalyst
9. Rate of removal of carbon nanotubes (if at all)

We are doing technology in multidimensional parameter space!!
Poster Session A: Synthesis

Five questions of science to answer:

1. Does surface of metal particle catalyse:
   (a) decomposition of hydrocarbon
   (b) decomposition of further metal precursor

2. What is the metallurgy of nano particles?
   (a) melting point, surface melting, internal pressure
   (b) carbon solubility (as function of radius)
   (c) phase diagram with carbon, (modelling+experiment)

3. Does a region of metal particle have to remain free of a graphene coating? If it doesn’t, is that a killer?
Five questions of science to answer: (cont)

4. What determines rate of growth?
   (a) diffusion rate in metal (surface),
   (b) supply of carbon to particle,
   (c) shape changes due to flow of small (not necessarily molten) particles.
   (d) interface modifiers such as sulphur
   (e) do we have a reliable Ea yet?

5. What determines type and size of nanotube?
   (a) metal particle diameter and/or composition
   (b) temperature
   (c) feedstock
   (d) what is the difference in growth mechanism between (say) a double wall tube and an 8 ish layer multi-wall tube of similar diameter?
Thank You

Poster Session A: Synthesis