Session V: Graphene

Matteo Bruna
Graphene: Material in the Flatland

Properties:

- Thinnest imaginable material
- Good (and tunable) electrical conductor
- Strongest ever measured
- Stiffest known material (stiffer than diamond)
- Highly stretchable crystal (up to 20%)
- High flexibility
- Chemical stability
- High charge carrier mobility ($>10^6$ cm$^2$ V$^{-1}$s$^{-1}$)
- High transparency (97.7%)
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<thead>
<tr>
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- “Carbon Nanotubes and Graphene for Electronics Applications: Technologies, Players and Opportunities”, IDTechEx, 2010
### Large scale pristine graphene production

**Parameters**

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<th>Chemical Vapor Deposition</th>
<th>Carbon Segregation</th>
<th>Liquid Phase Exfoliation</th>
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<tr>
<td>Starting material</td>
<td>Hydrocarbon</td>
<td>Substrate itself</td>
<td>Natural graphite</td>
</tr>
<tr>
<td>Max. Temperature</td>
<td>High (1000 °C)</td>
<td>High (&gt;1000 °C)</td>
<td>Room temperature</td>
</tr>
<tr>
<td>Substrate</td>
<td>Cu or Ni</td>
<td>SiC</td>
<td>None</td>
</tr>
<tr>
<td>Major process steps</td>
<td>3 to 4</td>
<td>3 to 4</td>
<td>2</td>
</tr>
<tr>
<td>Area limited to</td>
<td>Substrate size (m)</td>
<td>Wafer size</td>
<td>Substrate size (&gt;m)</td>
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## Fields of potential application

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Graphene production, 2009-2017

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Graphene-inks for optoelectronics

1 nm = 1 Billionth of a meter
Graphene-inks for optoelectronics

![Graphene-inks for optoelectronics](image)

- Lateral size (nm)
- Number of flakes
- Number of Layers
- Counts

N=74
Inks adaptable to many present printing techniques

- Ink-jet
- Spray-coating
- Roll to roll
Graphene-inks for optoelectronics

Flexible transparent optoelectronic devices

Thin film transistors

Photovoltaic devices

Highly-doped Er\(^{3+}\) fiber
WDM
Pump laser
PC
ISO
Coupler
Graphene mode-locker
Output

Light
Transparent graphene electrode
Electrode
Polymer/graphene active layer
Graphene electrode
Transparent graphene electrode
Electrode
Graphene inks and CVD for optoelectronics

- Touch screen displays
- Electronic paper
- Photovoltaic cells
- Sensors
- Radio frequency tags
- Smart textile
Our speakers

Professor Ian Kinloch,
Professor of Materials Science,
The nanomaterials group,
University of Manchester (UK)

Dr Gordon Chiu,
VP, Grafoïd and Chief Scientist,
Focus Graphite (Canada)