Microwave plasma enhanced chemical vapor deposition synthesis and applications of few layer graphene.

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Menu

A taste of graphene

Synthesis of few layer graphene

Characterization

Growth mechanism

Applications

Outlook and conclusions
Introduction

Graphene, the mother of all graphitic allotropes

Introduction

History of a hype

J.M. Blakely & Tontegode (Surface Science)

Geim

Novoselov

Novoselov and Geim demonstrate graphene’s extraordinary electrical properties

Novoselov and Geim isolate graphene sheets by mechanical exfoliation

Iijima discovers carbon nanotubes

Kroto, Smally and Curl discover fullerenes

Surface segregation of carbon

Chemical vapor deposition synthesis of graphene

2006

2004

2002

2000

1998

1996

1994

1992

1990

1988

1986

1984

1982

1980

1978

1976

Graphene

Monolayer graphite

Number of publications
Introduction

Graphene synthesis techniques

- Proc. Natl. Acad. Sci USA, 102, 10451, 2005
- Solid State Communications 143, 92-100, 2007
- Nanotechnology 18, 135301, 2007
- Nano Letters, 7 (11), 3394, 2007
Experimental Setup

Iplas Cyrannus microwave plasma source

Side view

Top view

TM 012 mode
$n_e \sim 10^{13} / \text{cm}^2$
Few layer graphene synthesis

Scanning (left) and transmission (right) electron microscopy

Conditions:
Plasma mode: TM012 mode
Samples: Si/SiO₂, Mo, Pt, Ti, ...
Microwave power: 2000 W
Pressure: 40 Torr
Temperature: +/- 1000°C
Bias: 0 V
Gas: CH₄ / H₂ = 1 / 8
total gas flow 200 sccm

A. Malesevic et al., Nanotechnology, in press 2008
Few layer graphene synthesis

Qualitative analysis

A. Malesevic et al., Nanotechnology, in press 2008
Few layer graphene growth mechanism

SEM study

Scale = 1 µm

A. Malesevic et al., Nanotechnology, in press 2008
Few layer graphene growth mechanism

Modelling combination of molecular dynamics and monte Carlo simulations

Substrate: Nickel
Cluster: 30 Ni atoms
Temperature: 1100 K
Code: Maruyama

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Few layer graphene field emission

Field emission experimental results

![Diagram of field emission experiment](image-url)
Few layer graphene field emission

Field emission experimental results

![Graph showing current vs. electric field.](image_url)

- Current (pA) on the y-axis.
- Electric field (V/μm) on the x-axis.
- The graph includes a linear fit line with the equation:
  \[ y = -50.56848x + 16.55705 \]

20 μm distance

i-SUP, 22-25 April 2008, Bruges
Bioactivation with ss-DNA

Two-step chemical functionalisation

+ 10-undecenoic acid

254 nm

+ amino-modified FITC-labelled DNA

+ EDC

FITC
Bioactivation with ss-DNA

Confocal fluorescence microscopy

Si

Quartz
Titanium scaffolds for tissue regeneration

Principle

Ti \rightarrow \text{NaOH} \rightarrow \text{Na}_2\text{Ti}_5\text{O}_{11} \rightarrow \text{SBF} \rightarrow \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2

Ti \rightarrow \text{PECVD} \rightarrow \text{Ti + FLG} \rightarrow \text{NHO}_3 \rightarrow \text{TiO}_2 \rightarrow \text{SBF} \rightarrow \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2
Titanium scaffolds for tissue regeneration

SEM results

Ti + FLG → TiO₂ → Ca₁₀(PO₄)₆(OH)₂

SBF
Titanium scaffolds for tissue regeneration

Material analysis

Top view SEM
Morphology

Electron diffraction mapping
RGB Comp Ti-Ca-P
Outlook & Conclusions

- MW PECVD Synthesis of FLG:
  - No catalyst required
  - Compatible with industrial techniques

- Properties of as grown flakes:
  - 4-6 layers thick
  - Highly crystalline
  - Few defects

- Three step growth mechanism

- Potential applications:
  - Promising field emission behavior
  - Potential DNA biosensor devices
  - Titanium scaffolds for tissue regeneration
Acknowledgements

Chris Van Haesendonck b
Alexander Volodin b
Annemie Bogaerts e
Annick Vanhulsel a
Axel Maeyens d
Eric Neyts e
George Dinescu d
Gustaaf Van Tendeloo c

Liang Zhang c
Manish Pal Chowdhury b
Matthieu Ravelingien
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