GRAPHITE TO GRAPHENE VIA GRAPHENE OXIDE: OVERVIEW ON SYNTHESIS, PROPERTIES, AND APPLICATIONS

Satyendra Mishra*, Navinchandra G. Shimpi, Dharmesh P. Hansora

**University Institute of Chemical Technology
North Maharashtra University, Jalgaon-425001
Maharashtra, India**

***profsm@rediffmail.com**

Nanostruc 2014, 19-21 May, 2014, Madrid

Objectives

- To discuss the most recent progress on graphene-related nanomaterials, including doped graphene and derived graphene nanoribbons, graphene oxide, graphane, fluorographene, graphyne, graphdiyne, and porous graphene, from both experimental and theoretical perspectives.
- To overview briefly of the synthesis, properties, and applications of graphene and related materials and emphasize tuning their stability, electronic and magnetic properties by chemical functionalization.
- To discuss synthesis and characterization of graphene oxide, graphene sheets from graphite using new continuous running underwater arc-discharge technique.

Introduction

- Up to 1980s:

Carbon Materials are

- ✓ **Diamond**
- ✓ **Graphite**

- Since 1980s:

Carbon Materials are

- ✓ **Fullerene (Bucky balls)**
- ✓ **Carbon Fibers**

- Now a days:

Carbon Materials are

- ✓ **Carbon Nanotubes**
- ✓ **Graphene sheets**
- ✓ **Graphene derivatives**

Introduction

- Graphene is the basic structural unit of some carbon allotropes, including graphite, carbon nanotubes (CNT) and fullerenes composed of benzene rings stripped of their hydrogen atoms.
- The rolling up of graphene along a given direction can produce a CNT.
- A zero-dimensional fullerene can also be obtained by wrapping-up graphene.

“When carbon fibres just won’t do, but nanotubes are too expensive, where a cost-conscious materials scientist can go to find a practical conductive composite?”

The answer could lie with graphene sheets”

- Graphene is considered a 2D carbon nanofiller with a one-atom-thick planar sheet of sp^2 bonded carbon atoms that are densely packed in a honeycomb crystal lattice.
- It is regarded as the “thinnest material in the universe” with tremendous application potential.

Introduction

Graphene-related carbon materials

(1) Graphene nanoribbons (GNRs)	(5) Graphyne and graphdiyne
(2) Graphene oxide (GO)	(6) Porous graphene
(3) Graphane	(7) Graphone
(4) Fluorographene	

Structure of (a) graphane, (b) graphyne, (c) graphdiyne and (d) graphone

Properties

- (1) Morphological and structure
- (2) Electronic
- (3) Mechanical
- (4) Optical
- (5) Thermal
- (6) Magnetic
- (7) Electrochemical
- (8) Electrical
- (9) Surface

Properties of graphene, CNT, nano sized steel, and polymers

Materials	Tensile strength	Thermal conductivity (W/mK) at room temperature	Electrical conductivity (S/m)
Graphene	130±10 GPa	$(4.84 \pm 0.44) \times 10^3$ to $(5.30 \pm 0.48) \times 10^3$	7200
CNT	60–150 GPa	3500	3000–4000
Nano sized steel	1769 MPa	5–6	1.35×10^6
Plastic (HDPE)	18–20 MPa	0.46–0.52	Insulator
Rubber (natural rubber)	20–30 MPa	0.13–0.142	Insulator
Fiber (Kevlar)	3620 MPa	0.04	Insulator

Applications & Markets

Flexible solar cell

Large-screen display

Touch screen device

Graphene Oxide (GO)

Polymer additive

Catalyst for organic reactions

Electrode

Applications & Markets

Experimental

Synthesis methods of Graphene

- (i) Chemical vapour deposition (CVD)
- (ii) Micromechanical exfoliation of graphite
- (iii) Epitaxial growth on electrically insulating surfaces, such as SiC
- (iv) Solution-based reduction of GO

Current synthesis method of Graphene

- Continuous running underwater Arc-Discharge technique

Materials required for Arc-discharge method

- Carbon metal electrodes of research grade graphite (M/s Schurtz Carbon Electrodes Pvt. Ltd., Gandhinagar, Gujarat, India).
- Tungsten, carbon and copper metal electrodes (scrap materials)
- DM water was used as a continuous medium
- Ice-bath for continuous cooling purpose

(a) Schematic representation of experiment setup

Experimental

Experimental set up of Batch process

Batch Experimental set up

Inter electrode Gap

Graphene sheets deposition

Filtration using filter paper

Experimental set up of continuous process

Experimental

Arc-struct and carbon deposition

Experimental

Schematic view

Purification steps

GS + 35 % conc. HCl + 30 min. Sonication

Separation using filter-paper to remove catalyst particles

3 times Ultra-centrifugation with DM water @ 5000 rpm for 10 min

Second time sonication with 35 % conc. HCl for 30 min.

3 times Ultra-centrifugation with DM water @ 5000 rpm for 10 min

Drying in oven @ 180 °C for 12 hours

Photographic view

Schematic cum photographic representation of purification steps

Results

Obtained yield obtained by continuous process

Sr. No.	Material uses as Cathode-Anode	Arc struc Time	Yield in gm	Type of structure obtained
1	Carbon-carbon	120 min	6.2	Stacked graphene nanosheets
2	Carbon-copper	120 min	2.8	Tubules wrapped graphene sheets
3	Carbon-tungston	120 min	2.2	Stacked graphene nanosheets

Characterization

Raman spectra of arc-struck deposits using electrodes
(a) carbon-carbon (b) carbon-copper and (c) carbon-tungsten

XRD of (a) graphite and (b) graphitic carbon nanosheets

TGA & DTG images (a) graphite and (b) graphitic carbon sheet

Characterization

(a) carbon-carbon

(b) carbon-copper

(c) carbon-tungsten

FE-SEM micrographs showing comparison between the microstructure of at different resolution

Characterization

(a) carbon-carbon

(b) carbon-copper

(c) carbon-tungsten

TEM micrographs of graphene sheets at different resolution

Possible Functionalization

- Research on graphene has progressed to second generation graphene-based materials that can be divided into two main categories:
 - Chemically modified graphene (CMG): i.e. graphene sheets where carbon atoms are replaced by other atoms (N, B, S, P) or entire functional groups;
 - 3D graphene architectures (3DG): i.e. systems constituted by graphene or CMG sheets assembled together to form 3D interconnected networks or very highly complex nano-objects like hollow nanospheres, crumpled paper, and capsules.

Surface modification of graphene

The general approaches for preparing organo-modified graphene are

- Chemical modification,
 - Reduction of GO in a stabilization medium,
 - Covalent modification of graphene,
 - Non-covalent functionalization of graphene,
 - Nucleophilic substitution and
 - Diazonium salt coupling.
- Electrochemical modification of graphene
 - π - π interaction

Conclusions

- This review endeavors to sum up the current status on different graphene derivatives including doped graphene, edge-functionalized graphene nanoribbons, oxidized graphene, hydrogenated and fluorinated graphene, graphyne, graphdiyne, porous graphene and graphone.
- Quantitatively and considerable cost effective yield of carbon nanostructured & nanocrystalline materials graphitic sheets are obtained by facile, cheapest, simple, and continuous running underwater arc-discharge method.
- It also shows a possibility of enhanced mass production of carbon nanostructured materials. In its basic form, the method requires only a DC power supply, metal-graphite electrode, with no need for pumps, seals, water-cooled vacuum chambers, or purge-gas handling systems.
- The system is easily adaptable to produce large quantities of nanotubes continuously without interruptions for electrode replacement, chamber cleaning, or gas purging. Arc-discharge technique is most suitable, cheaper & easier to implement for industrial-scale production due to its superior controllability and scalability for facilitating an efficient formation of graphitic nanosheets.
- It can be shown that graphene demonstrates at best its potential as a technological material whenever good electronic conduction, easy functionalization and a versatile nanodesign are necessary, e.g. in fuel cell electrodes, supercapacitors and batteries.

Research Group

Thank you

Create something for yourself which is easily realised 😊 😊