Loughborough University

22MPC312
Nanomaterials

Semester 1 2022/23 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **ALL** Questions

1. (a) Carbon nanomaterials all share similar electrical properties. What causes this? [4 marks]

(b) Carbon nanomaterials can come in various forms. The table below contains several different properties of carbon nanomaterials:

Table Q1. Selected data for Carbon Nanomaterials

Material	Carbon Quantum dot	Graphene nanoribbon	Graphene	Carbon nanotube
Form	-	Armchair	-	Single-walled, Chiral
Thermal Conductivity ($Wm^{-1}K^{-1}$)	6	218	5000	3000
Electrical Conductivity (Sm^{-1})	>1 x 10^3	20 x 10^6	80 x10^6	1 x 10^6
Band gap (eV)	1.74-2.5	0.1	0	0.2
Specific Surface Area (m^2g^{-1})	2	2630	2630	1315
Young's Modulus (TPa)	1	1	1	1
Transparency (%)	~50	97.4	97.4	90

(i) Which of the above nanomaterials would be suitable for a transistor device? Explain your reasoning. More than one nanomaterial may be suitable. [4 marks]

(ii) Discuss three advantages and three disadvantages of using nanomaterials in transistor devices compared to traditional, bulk transistor devices. [6 marks]

(iii) In Table Q1, carbon quantum dots have a variable band gap. Explain why the band gap of quantum dots can be changed. [4 marks]

(iv) Identify a potential application for quantum dots and briefly justify your selection. [2 marks]

2. (a) Define zero-dimensional nanomaterials and give an example thereof. [2 marks]

(b) Describe two different solution-based methods for synthesising zero-dimensional nanomaterials, making a statement on the efficacy of each method. [8 marks]

(c) Categorise the following methods of nanomaterial synthesis as either “top-down” or “bottom-up” approaches:

Focus ion beam milling
Chemical Vapour Deposition
Mechanical Exfoliation
Hot injection method
Sol-gel processing

[5 marks]

(d) A sample contains 150 mg of gold nanoparticles (density: 19.3 mg/mm^3, shape: perfect sphere). The diameter (D) of each nanoparticle is 1 nm.

Given that the surface area (SA) of a sphere is:

$$SA = \pi D^2,$$

and the volume (V) is:

$$V = 1/6\ \pi D^3$$

Calculate the specific surface area of the nanoparticles in m^2/g. Give your answers to four significant figures. [5 marks]

3. (a) TiO_2 nanoparticles are used in water purification and are prepared on a large scale using the flame aerosol process.

(i) Describe how TiO_2 nanoparticles are produced by the flame aerosol process, giving the relevant precursor used. [5 marks]

(ii) Explain why TiO_2 can be used in water purification and discuss the importance of nanoparticle size. [5 marks]

(iii) Discuss two advantages and two disadvantages of using TiO_2 nanoparticles for water purification. [4 marks]

(iv) Suggest another application for TiO_2 nanoparticles. [1 mark]

(b) Inorganic nanoparticles can be produced by mechanochemical processing.

(i) Describe this processing technique. [2 marks]

(ii) Discuss the advantages of this processing technique. [3 marks]

END OF PAPER

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