

23MPC312
Nanomaterials

Semester 1 2023/24

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. Each question carries 20 marks.

1. Nanomaterials are currently used widely in photovoltaics.
- (a) Describe the structure of buckminsterfullerene, highlight at least three distinctive characteristics. What impact does this have on the properties? [6 marks]
 - (b) What considerations need to be made when using buckminsterfullerenes in organic solar cells? [4 marks]
 - (c) Quantum dots can also be used in photovoltaic devices. Compare the structures and properties of quantum dots and buckminsterfullerenes. [5 marks]
 - (d) State an application for quantum dot solar cells. Give two advantages and two disadvantages of using quantum dots for this application. [5 marks]
2. (a) The formation of carbon nanotubes can result in different structural configurations. Describe how these differences can arise, and what the implications are for nanotube conductivity. [4 marks]
- (b) You have been asked to produce a carbon nanotube transistor device. Compare Chemical Vapour Deposition and Arc Discharge methods for this purpose, commenting on any additional steps that may be needed. [6 marks]
 - (c) Considering a liquid precipitation process, explain how to control growth and prevent aggregation of nanoparticles. [4 marks]
 - (d) A sample contains 450 mg of gold nanoparticles (density: 19.3 mg/mm³, 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:
$$V = 1/6 \pi D^3$$
 - (i) Calculate the surface area of nanoparticles. [4 marks]
 - (ii) Calculate the surface to volume ratio. [1 mark]
 - (iii) Calculate the specific surface area. [1 mark]

3. (a) You are going to produce a gold square pattern on a gold thin film by using E-beam lithography.
- (i) Describe the characters of this process. [3 marks]
 - (ii) Discuss the advantages and disadvantages of this process. [3 marks]
- (b) TiO_2 nanoparticles can be used in water purification.
- (i) Describe how TiO_2 nanoparticles are produced by the sol-gel process. [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]

END OF PAPER

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