Unit title: Nanotechnology

Unit code: **K/601/0311**

QCF level: **4**

Credit value: **15**

Aim

This unit examines the role of nanotechnology at the interface of Chemistry, Biology, Physics and Engineering, especially its use in achieving effects not possible in individual atoms or bulk materials.

Unit abstract

This unit provides learners with an introduction to the fundamental principles and commercial use of nanotechnology and embraces the interdisciplinary nature of the subject. Scientific theory relevant to the nanoscale is covered. Learners will also cover key concepts in engineering, physics, chemistry and biology and their application in solving nanotechnology problems.

Learners will develop practical skills and techniques to evaluate current nanotechnology fabrication methods. Current and potential future, applications in energy, medicinal engineering, physics, chemistry, biology, electronics and computing are covered.

Learners will gain an appreciation of the commercial applications of nanotechnology and the challenges for the future.

Learning outcomes

On successful completion of this unit a learner will:

1 Know how structure controls properties at the nanoscale dimension

2 Understand key concepts in engineering, physics, chemistry, and biology used to solve nanotechnology problems

3 Be able to evaluate current nanotechnology fabrication methods

4 Know current and potential future commercial nanotechnology applications.

Unit content

1 **Know how structure controls properties at the nanoscale dimension**

'There's plenty of room at the bottom': benefits of reducing a problem to the nanoscale; the nanoscale paradigm

Nanoscience: definitions; history; current commercial applications; nanoscale science; technology principles

Control of properties: Carbon Nanotube Technologies (CNT) eg from diamond to graphite to graphene to buckminster-fullerene to CNT, fabricating and key applications of carbon allotropes

Lengthscale controls of electronic properties: quantum devices; quantum dots; quantum wires; quantum wells; quantum computing

2 **Understand key concepts in engineering, physics, chemistry, and biology used to solve nanotechnology problems**

Surface and colloid chemistry: principles of surface/colloid chemistry; function of surfaces in nanotechnology devices; colloid chemistry and particles in nanotechnology

Thin film applications: thin film deposition and characterisation processes; plasma deposition/surface treatment; applications of thin film technology

Chemical templating: soft chemical fabrication; templating molecules; sol-gel synthesis; opals and photonic crystals; 3-DOM materials

Quality control in nanofabrication: failure analysis; analysis and measurement techniques in nanoscience; imaging techniques eg SEM, SPM-AFM; surface and bulk materials analysis

3 **Be able to evaluate current nanotechnology fabrication methods**

Nanofabrication: routes eg nanolithography, thin film processes, MEMS and semiconductors, physical limits to UV, X-ray and e-beam lithography, self-assembly, bottom-up fabrication and outline of Complex Adaptive Systems

Polymers and organic molecules: polymer chemistry applications in nanotechnology; organic molecules and supramolecular chemistry; liquid crystal and flat panel displays

Technology review: case study of the commercial application of nanotechnology; the company; how nanotechnology addresses a need, the technology; product and market

4 **Know current and potential future commercial nanotechnology applications**

Commercial applications: consumer markets for nanomaterials eg electronics, photonics, optoelectronics, magnetic data storage, MEMS/NEMS, nano-bio applications, computing technologies (present and future), nano-medicine

Moore's Law: semiconductors; history and future 1950-2020; material requirements for silicon; quantum effects (desired or not); nanofabrication techniques in semiconductors

Nanotechnology challenges: challenges eg skilled workforce, public and private investment, enhanced material risks of nanoparticles, public perception

Career prospects: nanotechnology career prospects eg materials science and processing, nano-bio applications, bioinformatics, nanomagnetics, quantum computing, IT

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:		**Assessment criteria for pass** The learner can:	
LO1	Know how structure controls properties at the nanoscale dimension	1.1	describe the benefits of reducing a problem to the nanoscale
		1.2	outline the definitions, history and current commercial applications of nanoscience
		1.3	describe the control of properties by structure in the carbon allotropes
		1.4	define the lengthscale controls of electronic properties
LO2	Understand key concepts in engineering, physics, chemistry, and biology used to solve nanotechnology problems	2.1	explain the principles of surface/colloid chemistry
		2.2	discuss thin film deposition and characterisation processes
		2.3	explain chemical templating
		2.4	compare imaging techniques for quality control in nanofabrication
LO3	Be able to evaluate current nanotechnology fabrication methods	3.1	carry out an assessment of different nanofabrication routes to an assigned device design
		3.2	plan commercial nanofabrication routes for the assigned device
		3.3	produce a report assessing cost, quality and safety of the planned route
		3.4	present the findings and make recommendations
LO4	Know current and potential future commercial nanotechnology applications	4.1	describe commercial applications of nanomaterials
		4.2	state Moore's Law and materials requirements for its continuation in silicon to 2020
		4.3	outline current challenges to nanotechnology
		4.4	describe future growth areas in nanotechnology including career prospects

Guidance

Links

This unit has particular links with the following units within this qualification:

Essential requirements

Delivery

It is assumed that nanotechnology experimentation is not possible in the learning environment. However, any nanoscience that facilities and/or health and safety permit will be hugely beneficial, for example colours of solutions of CdSe nanoparticles of different sizes. Visits to a nanofabrication facility would also add interest and context to the unit content.

Delivery of learning outcome 1 must focus on how property and function are controlled by dimensionality and lengthscale. A historical context starting with Feynman's famous 'there's plenty of room at the bottom' lecture would be of great benefit.

For learning outcome 2, appreciation of complex three-dimensional structures should be reinforced by the use of computer 3D imagery where possible.

Learning outcome 3 requires a project-based review of a commercial application of nanotechnology. This must be a product or technology that is being prepared for market, but it does not have to be on the market yet. Learners must review the technology, the product and how nanotechnology meets a specific need. The report must focus on four key areas; the company, the nanofabrication technology, the nano-aspects of the product and the market.

For learning outcome 4, emphasis must be placed on the safety implications of working with nanosized particles. Appropriate software and ICT facilities should be used to encourage independent learning.

Assessment

For learning outcome 1, learners must demonstrate knowledge of the role structure and dimensionality play in determining the physical properties of nanostructures, and outline the history and current state of nanotechnology.

For learning outcome 2, learners must explain the underlying chemical and physical concepts in surface/colloid science, chemical templating and thin film deposition. They must assess the use of the various imaging techniques for quality control and the characterisation of typical structures each technique produces.

For learning outcome 3, learners could work individually or in small groups to produce a report and presentation. If group work is selected, each learner must provide sufficient evidence to meet the assessment criteria on an individual basis. The relative merits of various possible fabrication strategies should be evaluated. One of these strategies must be selected on the basis of this evaluation and then related commercial and safety implications assessed.

For learning outcome 4, learners must demonstrate knowledge of the current challenges and potential future directions of nanotechnology, and the materials implications for the continuation of Moore's Law over the next 10 years.

Resources

Learners need access to library and ICT resources to support unit delivery.

Employer engagement and vocational contexts

Learners will benefit from visits to laboratories engaged in investigations or research into nanotechnological processes, for example in chip or hard-disk fabrication, agri-food research or nano-medicine. This would enable learners to observe the application of nanofabrication techniques within a particular context.

