36 Nanofabrication Technologies

Review Questions

36.1 What is the range of feature sizes of entities associated with nanotechnology?

Answer: Features sizes range from less than 1 nm to 100 nm (1×10^{-9} m to 100×10^{-9} m).

36.2 Name and define the three categories of nanotechnology products and applications.

Answer: The three categories identified in this chapter are (1) incremental, (2) evolutionary, and (3) radical. Incremental nanotechnology refers to products and applications in which great numbers of nanoscale particles are used to produce materials with unique and worthwhile properties or characteristics that could not be achieved using larger particles. Evolutionary nanotechnology involves the use of nanoparticles in great numbers that each accomplishes some unique and worthwhile purpose; that is, the nanoparticles function individually. Radical nanotechnology is concerned with the construction of microscopic machines that consist of nanoscale features and mechanisms.

36.3 Identify some of the present and future products associated with nanotechnology.

Answer: Products mentioned in the text include computers, flat screen displays, and batteries based on carbon nanotubes; nanodots and nanowires as reinforcing agents in composite materials; include cleaning cloths with nanofabrics, car polishes with nanoparticle waxes, and bullet proof vests. cancer drugs designed to match the genetic profile of cancer cells; surface films that absorb more solar energy than current photovoltaic receptacles; nanoscale coatings to increase scratch resistance of surfaces and stain resistance of fabrics; portable medical devices that provide fast analysis of a variety of medical testing such as pregnancy tests and ailments such as diabetes and HIV, and light sources that are more energy efficient.

36.4 What is a *bucky ball*?

Answer: A bucky ball is the carbon molecule C_{60}, a molecule containing exactly 60 carbon atoms and shaped like a soccer ball. The 60 atoms are arranged symmetrically into 12 pentagonal faces and 20 hexagonal faces to form a ball. The more formal name for a bucky ball is fullerene.

36.5 What is a *carbon nanotube*?

Answer: A carbon nanotube is a molecular structure of carbon atoms possessing the shape of a tube. It has a typical size of a few nm in diameter and a length of 100 nm or so. Of interest are its mechanical and electrical properties. It can possess strength and stiffness properties exceeding those of steel, and it can be a conductor of electricity or a semiconductor.

36.6 Why is biology so closely associated with nanoscience and nanotechnology?

Answer: The close association of biology derives from the fact that the building blocks of biological organisms are in the same size range. For example, proteins range in size between about 4 nm and 50 nm.

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36.7 The behavior of nanoscale structures is different from macroscale and even microscale structures due to two factors mentioned in the text. What are those two factors?

Answer: The two factors mentioned in the text that differentiate nanoscale objects from much larger ones are (1) surface properties become much more important because a much higher proportion of a nanoscale object's atoms or molecules are at the surface, whereas in a larger object the internal atoms and molecules are relatively much more numerous; and (2) material behavior of nanoscale objects is influenced by quantum mechanics rather than bulk properties.

36.8 What is a scanning probe instrument, and why is it so important in nanoscience and nanotechnology?

Answer: A scanning probe instrument uses a very sharp probe, whose tip approaches the size of an atom, that moves along the surface of the specimen at a distance of only one nanometer in order to measure properties of the surface. This type of instrument is important because it permits images of the surface to be constructed that are on the scale of the surface atoms.

36.9 What is *tunneling*, as referred to in the scanning tunneling microscope?

Answer: Tunneling is a quantum mechanics phenomenon in which individual electrons in a solid material jump beyond the surface of the solid into space. The probability of electrons being in this space above the surface decreases exponentially in proportion to the distance from the surface. This sensitivity to distance is exploited in the scanning tunneling microscope by positioning the probe tip very close to the surface and applying a small voltage between the two. This causes electrons of surface atoms to be attracted to the small positive charge of the tip, and they tunnel across the gap to the probe.

36.10 What are the two basic categories of approaches used in nanofabrication?

Answer: The two basic categories are (1) top-down approaches, which adapt microfabrication techniques to nanoscale object sizes and (2) bottom-up approaches, in which atoms and molecules are manipulated and combined into larger structures.

36.11 Why is photolithography based on visible light not used in nanotechnology?

Answer: Because the wavelength of visible light is 400 to 700 nm, well beyond nanoscale.

36.12 What are the lithography techniques used in nanofabrication?

Answer: The lithography techniques discussed in the text are (1) extreme ultraviolet lithography, (2) electron beam lithography, (3) x-ray lithography, and (4) nano-imprint lithography.

36.13 How is nano-imprint lithography different from micro-imprint lithography?

Answer: Nano-imprint lithography is the same basic process as micro-imprint lithography except the deformed features of the resist are of nanoscale proportions.

36.14 What are the limitations of a scanning tunneling microscope in nanofabrication that inhibit its commercial application?

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Answer: The limitations of STM include (1) they must be carried out in a very high vacuum environment to prevent stray atoms or molecules from interfering with the process and (2) the surface of the substrate must be cooled to temperatures approaching absolute zero (-273°C or -460°F) in order to reduce thermal diffusion that would gradually distort the atomic structure being formed. These limitations make it a very slow and expensive process.

36.15 What is *self-assembly* in nanofabrication?

Answer: Self-assembly is a process in which entities at the atomic and/or molecular level combine on their own into larger entities, proceeding in a constructive manner toward the creation of some deliberate thing.

36.16 What are the desirable features of atomic or molecular self-assembly processes in nanotechnology?

Answer: The desirable features of atomic or molecular self-assembly processes include the following: (1) they can be carried out rapidly, (2) they occur automatically and do not require any central control, (3) they exhibit massive replication, and (4) they can be performed at or near atmospheric pressure and room temperature.

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