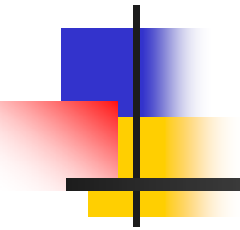


Quantum Wells, Wires, and Dots

QUANTUM WELLS, WIRES AND DOTS

- Quantum well
  : one dimension is reduced to the nano range while the other two dimensions remain large.

- Quantum wire
  : two dimensions are so reduced and one remains large.

- Quantum dot
  : the extreme case of this process of size reduction in which all three dimensions reach the low nanometer range

- Quantum
  : associated with these three types of nanostructures because the changes in properties arise from the quantum-mechanical nature of physics in the domain of the ultra small.

Preparation of quantum nanostructures

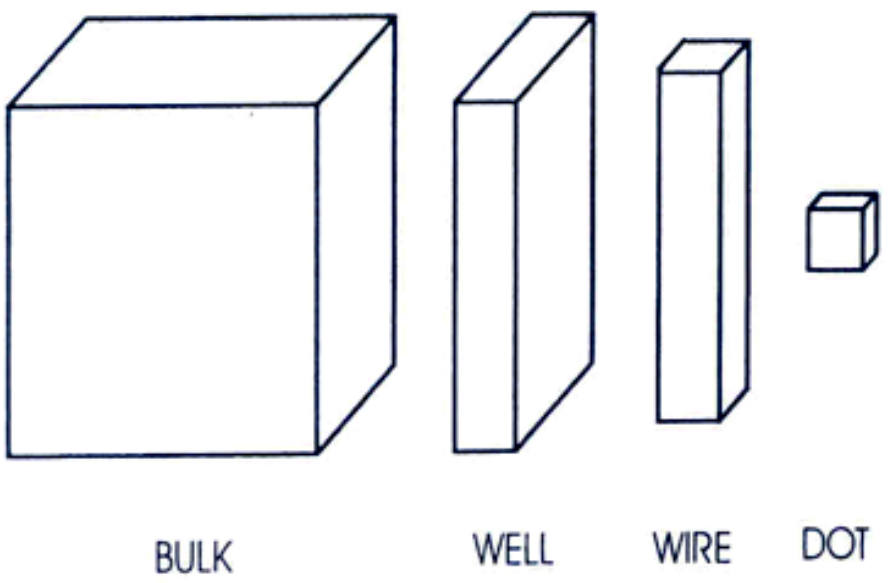


Figure 9.1 Progressive generation of rectangular nanostructure

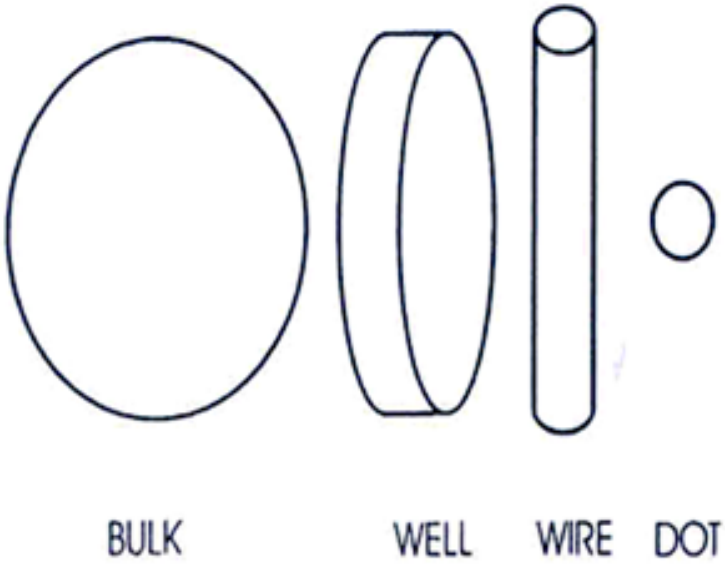


Figure 9.2 Progressive generation of curvilinear nanostructure

Preparation of quantum nanostructures

- Top-down method

- Lithography

  : shines radiation through a template on to a surface coated with a radiation-sensitive resist

  : the resist is then removed and the surface is chemically treated to produce the nanostructure.

- A typical resist material

  : the polymer polymethyl methacrylate $[C_5O_2H_8]_n$

  (a molecular weight in the range from 10^5 to 10^6 Da)

Preparation of quantum nanostructures

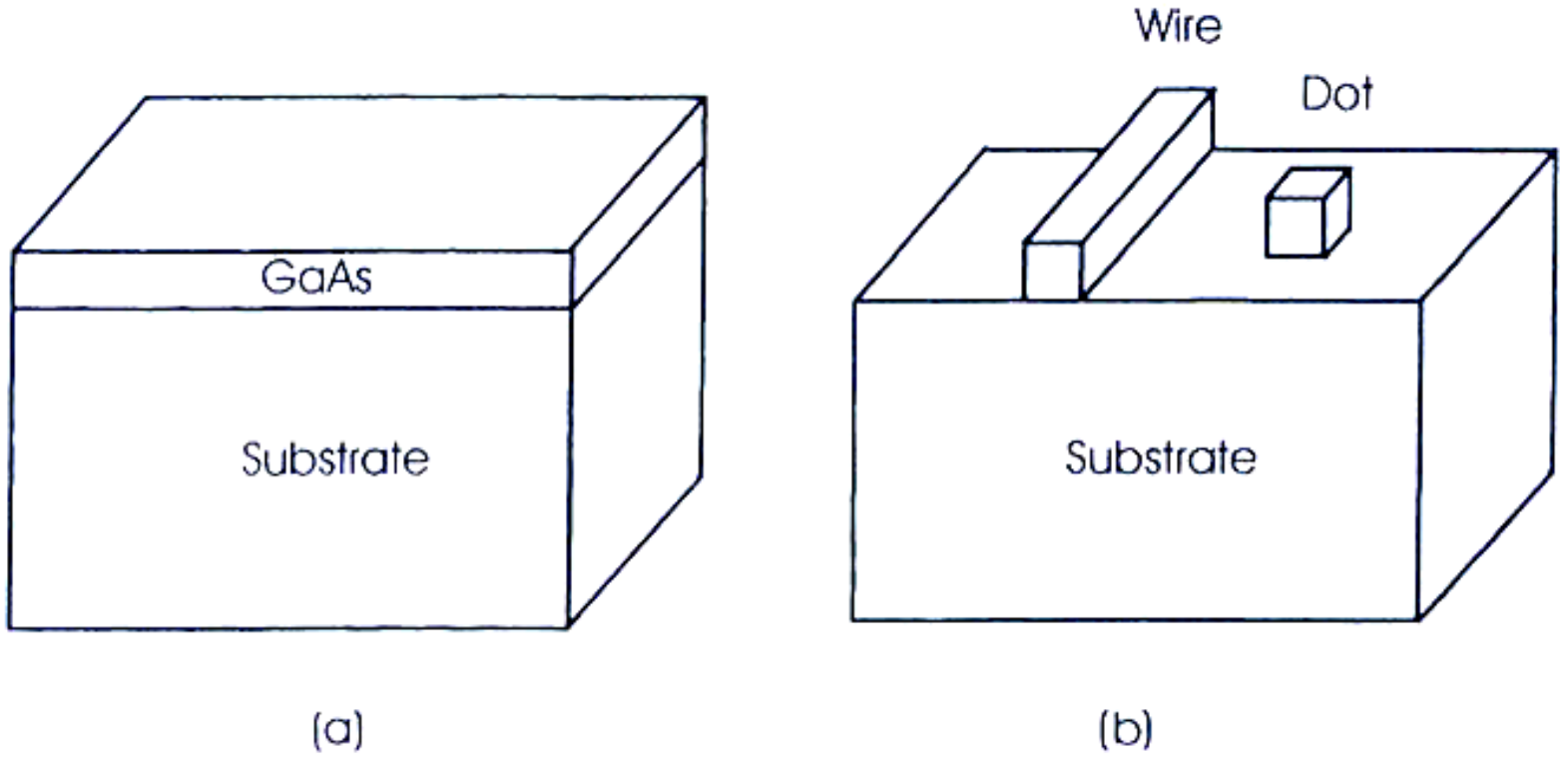
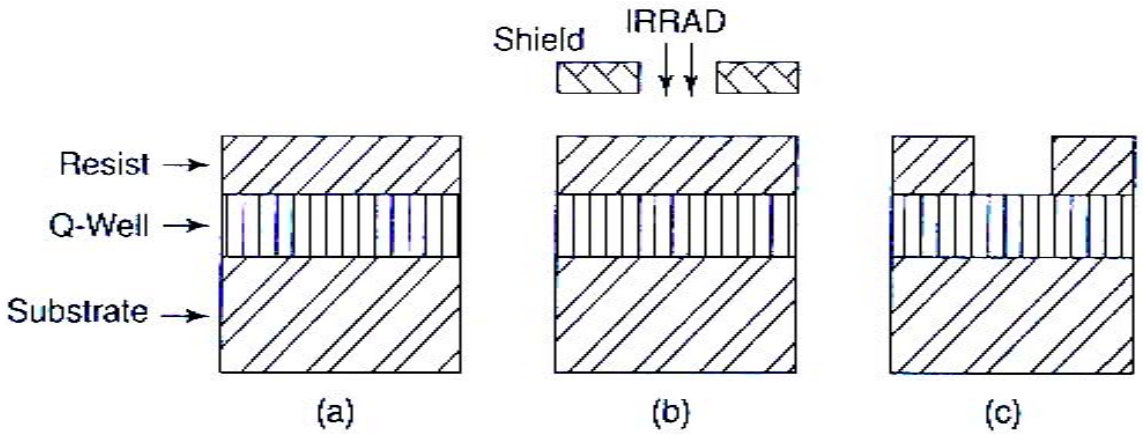


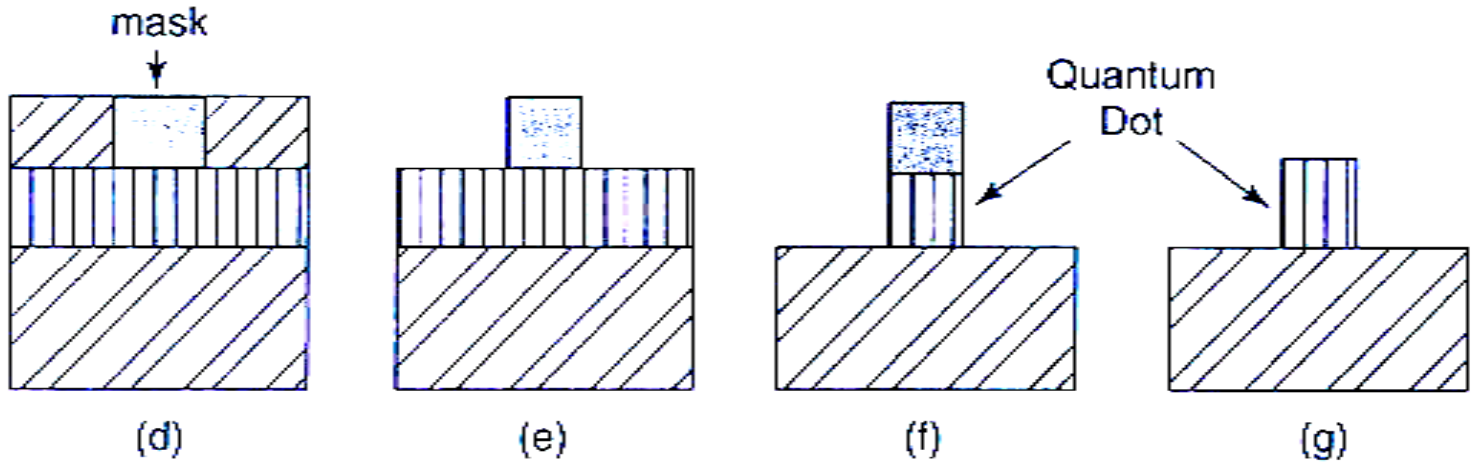
Figure 9.3 (a) Gallium arsenide quantum well on a substrate
(b) quantum wire and quantum dot formed by lithography

Preparation of quantum nanostructures



- The first step of the lithographic procedure is to place a radiation-sensitive resist on the surface of the sample substrate, as shown in (a).
- The sample is then irradiated by an electron beam in the region where the nanostructure will be located, as shown in the (b)
- This can be done by using either a radiation mask that contains the nanostructure pattern, or a scanning electron beam that strikes the surface only on the desired region. The radiation chemically modifies the exposed area of the resist so that it becomes soluble in a developer.
- The third step in the process(c) is the application of the developer to remove the irradiated portions of the resist.

Preparation of quantum nanostructures



- The fourth step (d) is the insertion of an etching mask into the hole in the resist
- Fifth step (e) consists in lifting off the remaining parts of the resist.
- Sixth step (f) the areas of the quantum well not covered by the etching mask are chemically etched away to produce the quantum structure
- Finally the etching mask is removed, if necessary, to provide the desired quantum structure (g)

Preparation of quantum nanostructures

- Electron-beam lithography : makes use of an electron beam for the radiation
- Other types of lithography : employ neutral atom beams(e.g., Li, Na, K, Rb, Cs), charged ion beams(e.g., Ga^{+}), or electromagnetic radiation such as visible light, X-ray.
- When laser beams are utilized, frequency doublers and quadruplers can bring the wavelength into a range (e.g., ~150nm)

  ->quantum-dot fabrication.
- Photochemical etching : applied to a surface activated by laser light.