Chapter#2

Nanostructures fabrication Techniques

There are generally two approaches of creating nanomaterials.

1) Top down approach
2) Bottom up approach

Bottom up approach uses self assembled properties, create larger units (nanoparticles) from individual molecules. On the other hands top down approach uses larger materials to make nano structures through lithography, ball milling and laser ablation etc.

Top-down approach

Lithography or pattern transfer techniques (Optical, e-beam & nanoimprint lithography)

Nanotechnology owes it existence to the astonishing development within the field of micro electronics. Since the invention of the integrated circuit nearly half a century ago in 1958, there has been an exponential growth in the number of transistors per micro chip and an associated decrease in the smallest width of the wires in the electronic circuits. As a result extremely powerful computers and efficient communication systems have emerged with a subsequent profound change in the daily lives of all of us.

Conventional microtechnology is a top-down technology. This means that the microstructures aref abricated by manipulating a large piece of material, typically a silicon crystal, using processes like lithography, etching, and metallization. The top-down approach to microelectronics seems to be governed by an exponential time dependence. In 1965, when the most advanced integrated circuit contained only 64 transistors, Gordon E. Moore, Director of Fairchild Semiconductor Division, was the first to note this exponential behavior in his famous paper *Cramming more components onto integrated circuits* [Electronics, **38**, No. 8, April 19 (1965)]: ”When unit cost is falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip”. He observed a doubling of the number of transistors per circuit every year, a law that has become known as Moore’s law.

It concerns the exponential decrease in the length of the gate electrode in standard CMOS transistors, with quoted values of 90 nm in 2003 and 65 nm in 2005 and ~10nm in 2019. Naturally, there will be physical limitations to the exponential behavior expressed in Moore’s law. However, also economic barriers play a major if not the decisive role in ending Moore’s law developments. The price for constructing microprocessor fabrication units also rises exponentially for each generation of microchips. Soon the level is comparable to the gross national product of a mid-size country, and that might very well slow down the rate of progress.

Clean room facilities

The small geometrical features on a microchip necessitates the use of clean room facilities during the critical fabrication steps. Each cubic meter of air in ordinary laboratories may contain more than 10^7 particles with diameters larger than 500 nm. To avoid a huge flux of these "large" particles down on the chips containing micro and nanostructures, micro and nanofabrication laboratories are placed in so-called clean rooms equipped with high-efficiency particulate air (HEPA) filtering system. Such systems can retain nearly all particles with diameters down to 300 nm. Clean rooms are classified according to the maximum number of particles per cubic foot larger than 500 nm. Usually a class-1000 or class-100 clean room is sufficient for microfabrication.

The low particle concentration is ensured by keeping the air pressure inside the clean room slightly higher than the surroundings, and by combining the HEPA filter system with a laminar air flow system in the critical areas of the clean room. The latter system let the clean air enter from the perforated ceiling in a laminar flow and leave through the perforated floor. Moreover, all personnel in the clean room must be wearing a special suit covering the whole body to minimize the surprisingly huge emission of small particles from each person.

Most of the particle-free air from the clean room itself is recirculated. However, since the exhaust air from equipment is not recirculated, there is also an intake of some fresh air.

Bottom up approach

In this approach, different physical, chemical and and green methods are used to synthesize nano materials. Wet chemicals methods include chemical reduction, hydrothermal method etc.

Chemical reduction method for synthesis of nanoparticles

$$\text{Main salt + Reducing agent} \longrightarrow \text{Nanoparticles + By products}$$