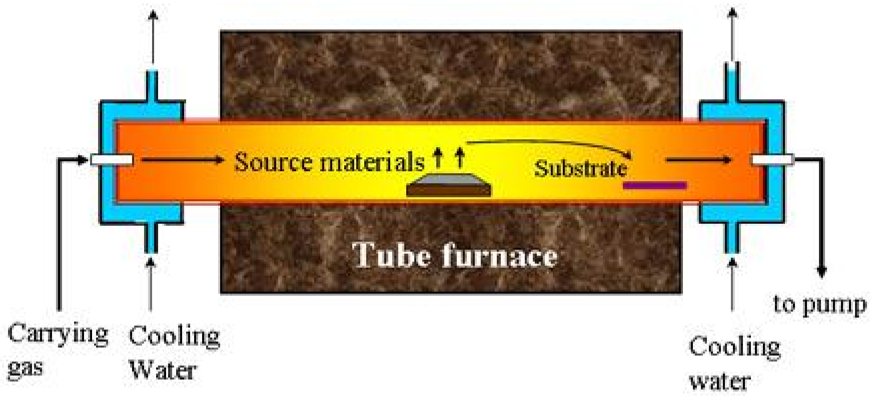
Physical Vapor Deposition Technique for Growing Nanostructures

Thermal evaporation is one of the simplest and most popular synthesis methods, and it has been very successful and versatile in fabricating nanobelts and nanowires with various characteristics. The basic process of this method is sublimating source material(s) in powder form at high temperature, and a subsequent deposition of the vapor in a certain temperature region to form desired nanostructures.



A typical experimental system is shown in Figure 1. The synthesis is performed in an alumina or quartz tube, which is located in a horizontal tube furnace. High purity oxide powders contained in an alumina boat are loaded in the middle of the furnace, the highest temperature region. The substrates for collecting the desired nanostructures are usually placed down-stream following the carrier gas. The substrates can be silicon wafer, poly-crystalline alumina or single crystal alumina (sapphire). Both ends of the tube are covered by stainless steel caps and sealed with O-rings. Cooling water flows inside the cover caps to achieve a reasonable temperature gradient in the tube.

During the experiments, the system is first pumped down to around 10-2 Torr. Then the furnace is turned on to heat the tube to the reaction temperature at a specific heating rate. An inert carrying gas, such as argon or nitrogen, is then introduced into the system at a constant flow rate to bring the pressure in the tube back to 200-500 Torr (different pressures are required by different source materials and final deposited nanostructures). The reaction temperature and pressure are held for a certain period of time to vaporize the source material and achieve a reasonable amount of deposition.

Source materials can be vaporized at the high temperature and low presure condition. The vapor is then carried by the innert carrying gas down to the lower temperature region, where the vapor gradually becomes supersaturated. Once it reaches the substrate, nucleation and growth of nanostructures will occur. The growth is terminated when the furnace is turned off. The system is then cooled down to room temperature with flowing inert gas.

The thermal evaporation process is basically a physical vapor deposition process and has been successfully used for synthesizing a variety of oxide and non-oxide nanobelts and nanowires. Moreover, this system can also be used for chemical vapor deposition (CVD) by simply applying reaction gases instead of the carrier gas and placing substrates in the middle of the tube. For example, multi-wall and single-wall carbon nanotubes have been successfully fabricated in this system using hydrogen and methane/acetylene as reactants. Metal catalysts, such as gold, tin, copper, etc. have also been used to achieve size control and alignment.