RAMA UNIVERSITY

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FACULTY OF ENGINEERING AND TECHNOLOGY

MEMS-035

Lecture -05

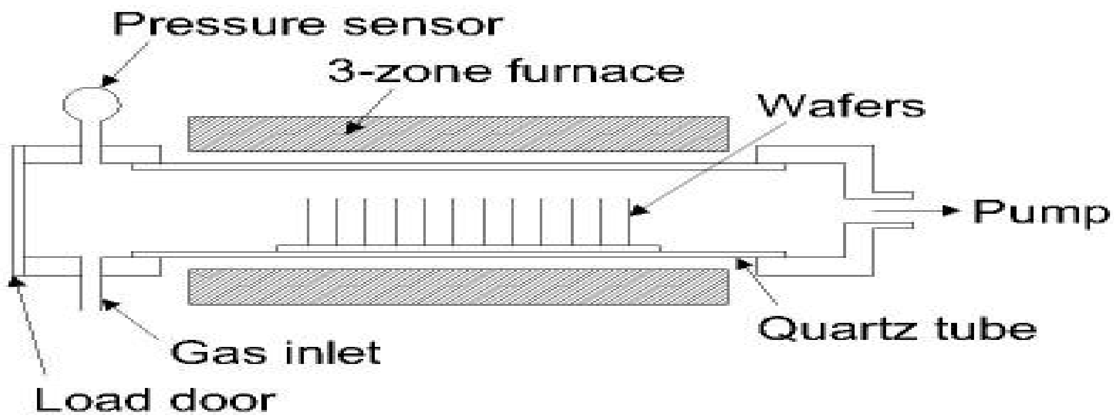
DEPOSITIONS THAT HAPPEN BECAUSE OF A **PHYSICAL** REACTION

- **P**hysical **V**apor **D**eposition (PVD)
- Casting

CHEMICAL VAPOR DEPOSITION (CVD)

The substrate is placed inside a reactor to which a number of gases are supplied. The fundamental principle of the process is that a chemical reaction takes place between the source gases. The product of that reaction is a solid material with condenses on all surfaces inside the reactor.

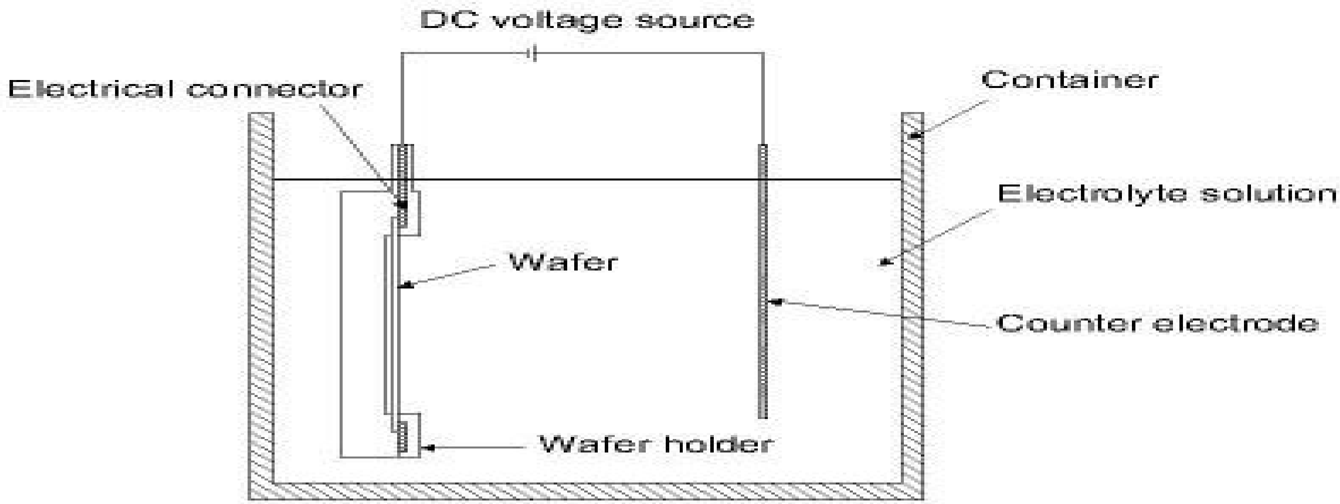
The two most important CVD technologies in MEMS are the **L**ow **P**ressure CVD (LPCVD) and **P**lasma **E**nhanced CVD (PECVD). The LPCVD process produces layers with excellent uniformity of thickness and material characteristics. The main problems with the process are the high deposition temperature (higher than 600°C) and the relatively slow deposition rate. The PECVD process can operate at lower temperatures (down to 300° C) thanks to the extra energy supplied to the gas molecules by the plasma in the reactor. However, the quality of the films tends to be inferior to processes running at higher temperatures. Secondly, most PECVD deposition systems can only deposit the material on one side of the wafers on 1 to 4 wafers at a time. LPCVD systems deposit films on both sides of at least 25 wafers at a time. A schematic diagram of a typical LPCVD reactor is shown in the figure below.



ELECTRO DEPOSITION\

This process is also known as "electroplating" and is typically restricted to electrically conductive materials. There are basically two technologies for plating: Electroplating and Electroless plating. In the electroplating process the substrate is placed in a liquid solution (electrolyte). When an electrical potential is applied between a conducting area on the substrate and a counter electrode (usually platinum) in the liquid, a chemical redox process takes place resulting in the formation of a layer of material on the substrate and usually some gas generation at the counter electrode.

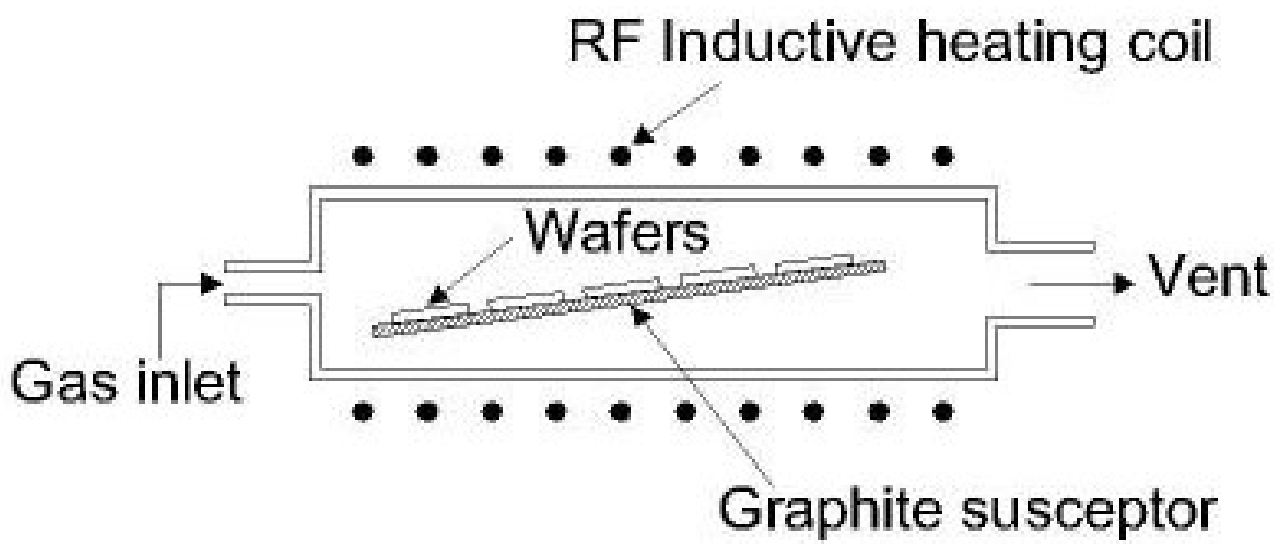
In the electroless plating process a more complex chemical solution is used, in which deposition happens spontaneously on any surface which forms a sufficiently high electrochemical potential with the solution. This process is desirable since it does not require any external electrical potential and contact to the substrate during processing. Unfortunately, it is also more difficult to control with regards to film thickness and uniformity. A schematic diagram of a typical setup for electroplating is shown in the figure below.



This technology is quite similar to what happens in CVD processes, however, if the substrate is an ordered semiconductor crystal (i.e. silicon, gallium arsenide), it is possible with this process to continue building on the substrate with the same crystallographic orientation with the substrate acting as a seed for the deposition. If an amorphous/polycrystalline substrate surface is used, the film will also be amorphous or polycrystalline.

There are several technologies for creating the conditions inside a reactor needed to support epitaxial growth, of which the most important is **V**apor **P**hase **E**pitaxy (VPE). In this process, a number of gases are introduced in an induction heated reactor where only the substrate is heated. The temperature of the substrate typically must be at least 50% of the melting point of the material to be deposited.

An advantage of epitaxy is the high growth rate of material, which allows the formation of films with considerable thickness (>100µm). Epitaxy is a widely used technology for producing silicon on insulator (SOI) substrates. The technology is primarily used for deposition of silicon. A schematic diagram of a typical vapor phase epitaxial reactor is shown in the figure below.


RF Inductive heating coil
Wafers
Vent
Gas inlet
Graphite susceptor

Physical Vapor Deposition (PVD)

PVD covers a number of deposition technologies in which material is released from a source and transferred to the substrate. The two most important technologies are

EVAPORATION

SPUTTERING.

EVAPORATION

In evaporation the substrate is placed inside a vacuum chamber, in which a block (source) of the material to be deposited is also located. The source material is then heated to the point where it starts to boil and evaporate. The vacuum is required to allow the molecules to evaporate freely in the chamber, and they subsequently condense on all surfaces. This principle is the same for all evaporation technologies, only the method used to the heat (evaporate) the source material differs. There are two popular evaporation technologies, which are e-beam evaporation and resistive evaporation each referring to the heating method. In e-beam evaporation, an electron beam is aimed at the source material causing local heating and evaporation. In resistive evaporation, a tungsten boat, containing the source material, is heated electrically with a high current to make the material evaporate. Many materials are restrictive in terms of what evaporation method can be used (i.e. aluminum is quite difficult to evaporate using resistive heating), which typically relates to the phase transition properties of that material

Sputtering

Sputtering is a technology in which the material is released from the source at much lower temperature than evaporation. The substrate is placed in a vacuum chamber with the source material, named a target, and an inert gas (such as argon) is introduced at low pressure. A gas plasma is struck using an RF power source, causing the gas to become ionized. The ions are accelerated towards the surface of the target, causing atoms of the source material to break off from the target in vapor form and condense on all surfaces including the substrate. As for evaporation, the basic principle of sputtering is the same for all sputtering technologies. The differences typically relate to the manor in which the ion bombardment of the target is realized.

CASTING

In this process the material to be deposited is dissolved in liquid form in a solvent. The material can be applied to the substrate by spraying or spinning. Once the solvent is evaporated, a thin film of the material remains on the substrate. This is particularly useful for polymer materials, which may be easily dissolved in organic solvents, and it is the common method used to apply photoresist to substrates (in photolithography). The thicknesses that can be cast on a substrate range all the way from a single monolayer of molecules (adhesion promotion) to tens of micrometers. In recent years, the casting technology has also been applied to form films of glass materials on substrates.

DEPOSITION

The act of applying a thin film to a surface is *thin-film deposition* – any technique for depositing a thin film of material onto a substrate or onto previously deposited layers. "Thin" is a relative term, but most deposition techniques control layer thickness within a few tens of nanometres. Molecular beam epitaxy allows a single layer of atoms to be deposited at a time.

It is useful in the manufacture of optics (for reflective, anti-reflective coatings or self-cleaning glass, for instance), electronics (layers of insulators, semiconductors, and conductors form integrated circuits), packaging (i.e., aluminium-coated_PET_film), and in contemporary_art (see the work of Larry_Bell). Similar processes are sometimes used where thickness is not important: for instance, the purification of copper by electroplating, and the deposition of silicon and enriched uranium by a CVD-like process after gas-phase processing.