Deposition Technique

Divya Aggarwal
University of Delhi, New Delhi

ABSTRACT

The technology behind the spectacular growth in the silicon semiconductor industry and continued trend in miniaturization has been fueled in large amount in last decade by improved thin film deposition techniques and the development of highly specialized equipment to enable this deposition. There are number of Physical Vapour Deposition and Chemical Deposition techniques to make these thin films. Each one of them is better than the other one. We will discuss in detail *Physical Vapour Decomposition (PLD, Thermal evaporation technique, sputtering) *Chemical Vapour Deposition.

Keywords: PLD: plasma laser decomposition; PVD: Physical vapour decomposition; CVD: chemical vapour decomposition; rf: radio frequency

THIN FILM:

Thin films has been used for many years i.e. more than 50 years for making
a.optics (reflective, anti reflective, coating)
b. electronics (insulator, semiconductors)
c. purification of cu, deposition of si

Thin film processing also saves on energy consumption in production and is considered an environmentally benign material technology for the next century. Thin film technology is both an old and a current key material technology.

DEPOSITION TECHNIQUES

" in February 2008, an accident leakage of toxic gases from sanitation tank on INS Jalashwa (second largest warship in the indian navy and formerly USS Trenton), led to the tragic loss of life of many Indian Navy Personnel" . There are so many incidents like this happening all over the country and here is where online gas sensors come into play which are made with the help of simple technique as Deposition technique.

It is of many types, two types are:

1. Physical decomposition
2. Chemical decomposition

Physical decomposition can be further subdivided into

1. PLD: Plasma Laser Decomposition
2. Thermal evaporation
    2.1 E-beam
    2.2 Filament

3. Chemical vapour decomposition
    3.1 spin coating
    3.2 plasma enhanced CVD
    3.3 atomic layer deposition
4 sputtering
    4.1 rf
    4.2 dc
    4.3 rf magnetron

5. molecular beam epitaxy

6. cathode arc deposition

7. electrodynamic deposition

Chemical decomposition can also be further classified but we would not read about it here in detail.

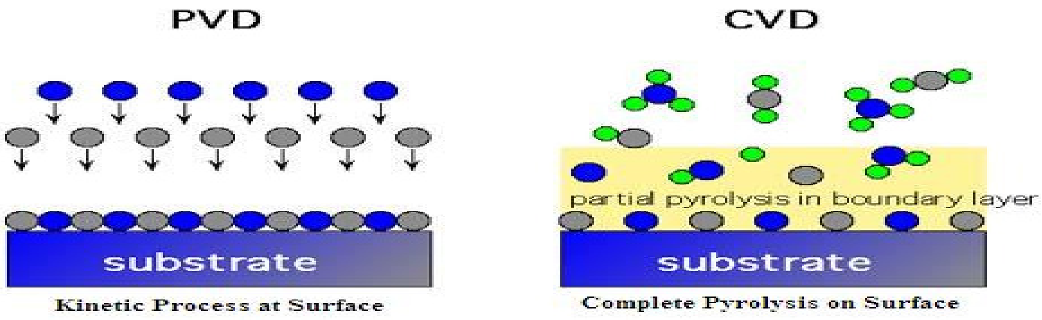


Fig. 4.1 Schematic representation of physical and chemical vapor deposition

6. PHYSICAL VAPOUR DEPOSITION

Physical Vapor Deposition (PVD) processes (often just called thin film processes) are atomistic deposition processes in which material is vaporized from a solid or liquid source in the form of atoms or molecules, transported in the form of a vapor through a vacuum or low pressure gaseous (or plasma) enviroment to the substrate where it condenses. Typically, PVD processes are used to deposit films with thicknesses in the range of a few nanometers to thousands of nanometers; however they can also be used to form multilayer coatings, graded composition deposits, very thick deposits and freestanding structures. The substrates can range in size from very small to very large such as the 10' x 12' glass panels used for architectural glass. The substrates can range in shape from flat to complex geometries such as watchbands and tool bits. Typical PVD deposition rates are 10–100Å (1–10 nanometers) per second. There are three types of PVD

a. Mechanical
b. Electrochemical
c. thermodynamic

This is directional rather than conformal, in this process low pressure is required.

The main categories of PVD processing are thermal evaporation, sputter deposition, ion plating and arc vapor deposition are:

1. molecular beam epitaxy:

a slow stream of gallium arsenide can be directed at the substrate, physically it is done with the help of furnance and chemically it is done with chemical beam epitaxy.

2. Electrodynamic deposition:

The solution in small capillary nozzle is connected to high voltage. Under Electric Field, liquids takes a conical shape and at apex disintegrates into thin fine, small positive charge droplets under Rayleigh’s charge. (small droplets get deposited)

3. Cathode arc deposition:

Ion beam deposition takes place in high power density, electrical arc is created which blasts ions from the cathode

5. Pulse Laser Deposition:

In this ultra high vaccum is required. The steps are as following-

4.1 laser ablation of the target material and creation ofa plasma
4.2 dynamic of the plasma
4.3 deposition of the ablation material on the substrate surface
4.4 Thermal deposition:

It has high purity due to lower pressure.only materials with much higher vapor pressure than heating element can be deposited.electric resistance heater meet the material and raise its vapour to a useful range. The source materials are evaporated by a resistively heated filament or boat, generally made of refractory metals such as W, Mo, or Ta, with or without ceramic coatings.

Evaporation system is of two types: E-Beam and filament.

The problems faced are:

- Poor step coverage which is resolved ny rotation of the substrate.
- Not form continous film for aspect ratio which is resolved by creating a high pressure.

Resistive evaporation: it uses relative heating to evaporate a metallic filament. Its drawback are that it is limited to low Melting point metals. Small filament size limits the deposit thickness.

E-beam evaporation: it is a stream of high energy electrons (5.30 Kev) to evaporate source material. It can evaporate any material.power upto 1200 KW is needed. Its drawback are that at T>10K incident electrons can produce X-Ray.

HEAT SOURCE	ADVANTAGE	DISADVANTAGE
Resistance	No radiation	Contamination
e-beam	Low contamination	Radiation
RF	No radiation	Contamination
Laser	No radiation, low contamination	expensive

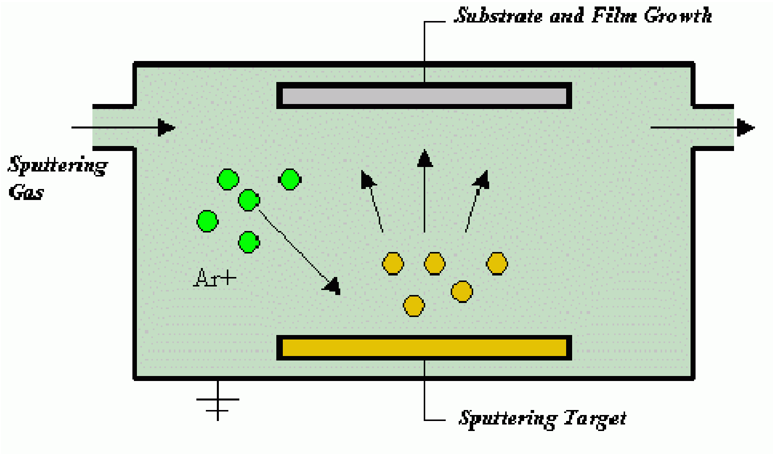
7. SPUTTERING

sputtering is a non-thermal vaporization process where the momentum exchange between the energetic ions and atoms in the target material due to collisions takes place. This PVD process is sometimes just called “sputtered films of —” which is an improper term in that the film is not being sputtered. Sputter deposition can be performed by energetic ion bombardment of a solid surface (sputtering target) in a vacuum using an ion gun or low pressure plasma (<5 mTorr) where the sputtered particles suffer few or no gas phase collisions in the space between the target and the substrate. Sputtering can also be done in a higher plasma pressure (5–30 mTorr) where energetic particles sputtered or reflected from the sputtering target are “thermalized” by gas phase collisions before they reach the substrate surface. The plasma used in sputtering can be confined near the sputtering surface or may fill the region between the source and the substrate. The sputtering source can be an element, alloy, mixture, or a compound and the material is vaporized with the bulk composition of the target. Sputter deposition is widely used to deposit thin film metallization on semiconductor material, coatings on architectural glass, reflective coatings on compact discs and decorative coatings.

The disadvantage of sputtering is:

- Substrate damage due to low bombardment
- Deposition rate quite slow
- Most of the energy becomes heat which must be removed.
- It is god for ohmic and not for schotky device.

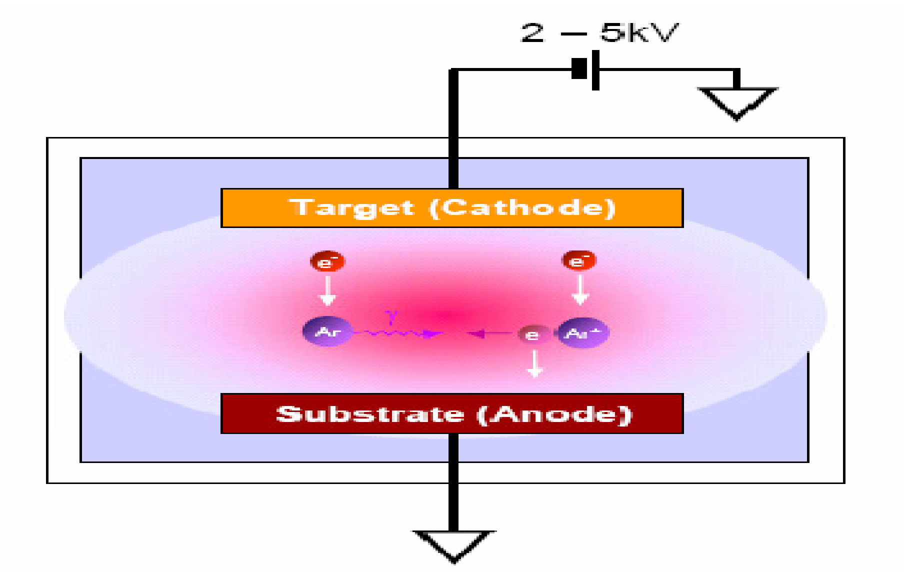
The advantage of sputtering is:
- Better step coverage
- Less radiation damage than electron beam evaporation.
- Easier to deposit alloys.



There are few mays of sputtering-rf, dc, magnetron.
1. *DC Sputtering:*
2. *Rf Sputtering:*
3. *Magnetron*

7.1. DC Sputtering

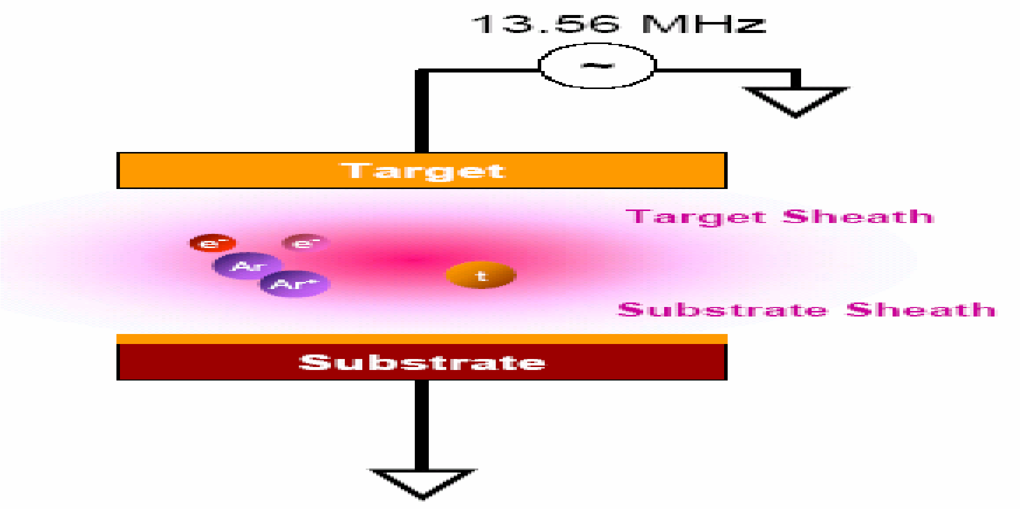
During DCdiode sputtering the atoms that leave the target with typical energies of 5 eV undergogas scattering events in passing through the plasma gas; this is so even at low operating pressures. As a result of repeated energy-reducing collisions they eventually thermalize or reach the kinetic energy of the surrounding gas. This happens at the distance <xth>, is the mean distance from the cathode sputtered atoms travel before they become thermalized, where their initial excess kinetic energy, so necessary to provide bombardment of the depositing film, has dissipated. No longer directed, such particles now diffuse randomly. Not only is there a decrease in the number of atoms that deposit, but there is little compaction or modification of the resulting film structure.this is used for only metallization and not for oxides (cathode behave as dielectric)



7.2. RF Sputtering

In contrast dealing with the issue of sustaining AC discharges in an electrodeless environment, our present concern is with sputter deposition. If a convenient level of V = 100 V is set, it means that a target with a resistivity exceeding 106 Ω-cm could not be DC sputtered. This impasse can be overcome, however, if we recall that impedances of dielectric filled capacitors drop with increasing frequency. Therefore, high-frequency plasmas ought to pass current through dielectrics the way DC plasmas do through metal targets. And since the sputter yields are essentially similar for both target materials, sputtering of a dielectric cathode in an AC plasma should be feasible. It is good for insulating material. Alternating voltage is given as the positive charge starts building on the cathode i.e. target.

If f<50KHz , DC sputtering of both surface
If f>50KHz , ions no longer follow the switching.
It can operate at lower Ar pressure (1-15mTorr)



7.3 Magnetron Sputtering

For reasons given earlier as well as others that follow, magnetron sputtering is the most widely used variant of DC sputtering. Magnetron sputtering is practiced in DC and RF as well as reactive variants and has significantly enhanced the efficiency of these processes.it works at lower Ar pressure and uses both electric as well as magnetic field. It increase electron path length and has more ionization near cathode. Fewer electrons reach substrate thus resulting in less heating. The disadvantage is that target degrade very fast.

REFERENCE

[1] Information on http://en.wikipedia.org/wiki/Physical_vapor_deposition
[2] Informattion on http://en.wikipedia.org/wiki/Sputtering
[3] Information on http://www.wisegeek.org/what-is-rf-sputtering.htm
[4] kajal jindal; Development of doped ZnO thin films exhibiting multifunctional properties for sensing devices. Thesis submitted to the university of delhi
[5] Divya Haridaas; studies on SnO2 thin film gas sensors for LPG nad Methane
[6] presentations of various p.hd. students of University Of Delhi