Annals of Natural Sciences
Vol. 5(2), June 2019: 1-7
Journal's URL: http://www.crsdindia.com/ans.html
Email: crsdindia@gmail.com

e-ISSN: 2455-667X
Annals
of
Natural Sciences

ORIGINAL ARTICLE

A Review of Metal Organic Chemical Vapor Deposition (MOCVD) Technique

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ABSTRACT

Metal organic chemical vapor deposition (MOCVD) is a widely used method for preparing epitaxial structure by depositing atoms on a wafer for broad variety of applications in opto-electronics, industry and research. The desirable feature of the MOCVD process includes thickness uniformity, high decomposition rate, and control over stochiometery of deposited material and sharp interfaces.

Key words: *MOCVD, Review Report, opto-electronics, industry*

Received: 9th Feb. 2019, Revised: 21st March 2019, Accepted: 2nd April 2019

How to cite this article:
Aithekar V. and Samotya V. (2019): A Review of Metal Organic Chemical Vapor Deposition (MOCVD) Technique. Annals of Natural Sciences, Vol. 5[2]: June, 2019: 1-7.

INTRODUCTION

MOCVD is specialized area of CVD, which utilizes metal-organic compounds as usually in combination with hydries or other reactant. Wide verity of materials can be deposited by MOCVD either as single crystal, polycrystalline or amorphous film. The most important application is for deposition of group III-V semiconductor compounds such as gallium arsenide (GaAs), Indium arsenide (InAs), Indium phosphate (InP) and gallium aluminum phosphate (GaAlP) etc. These materials are based in devices such as light emitting diode, solid-state lasers, photovoltaic cell, IR detector and hetrojuction bipolar transistors. Using MOCVD we can build up many layers each of a precisely controlled thickness to create a material, which has specific optical and electrical properties. Using this technique it is possible to build rang of semiconductor photo detector and laser. For realization of any semiconductor device, first process is grown the crystal with different layers of materials doping concentration for this wok MOCVD is being used for crystal growth.

The principle of MOCVD is quite simple, in which atoms are deposited by decomposing organic molecules while they are passing over the hot substrate. MOCVD has been established as a very useful fabrication process for depositing of high quality films particularly in microelectronic application as it offers advantages of selective growth conformal setup coverage, large scale capability and excellent uniformity in layer thickness.

MOCVD REACTION MECHANISM

MOCVD is a basic and most commonly used compound semiconductor growth technique. This involves the forced convention of metal organic vapor species over heated crystal release the desired species, resulting in crystal growth. For example indium phosphide could be grown in a reactor on a substrate by introducing trimethyl indium ((CH$_3$) in) and phosphine (PH$_3$) is shown in the figure 1.

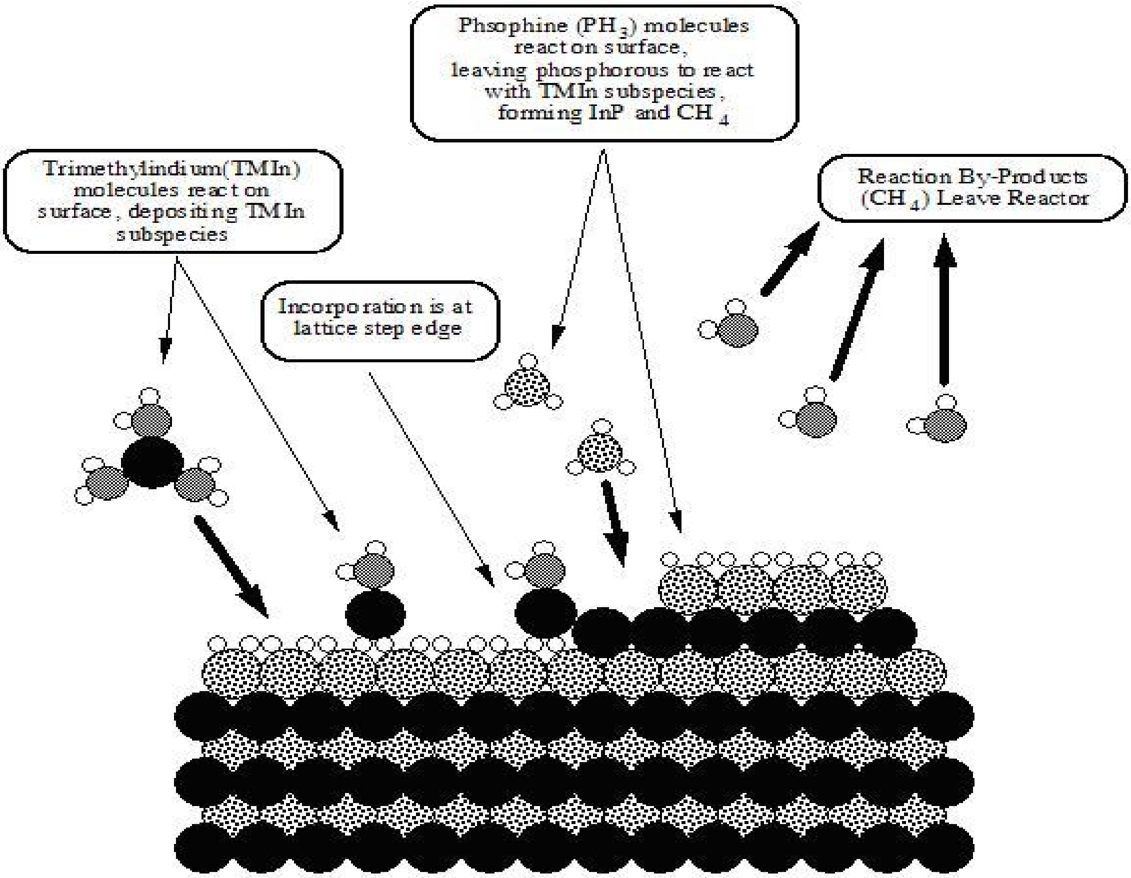

Fig. 1: show the grown of indium phosphide in a reactor on a substrate by introducing trimethyl indium ((CH_3) in) and phosphine (PH_3)

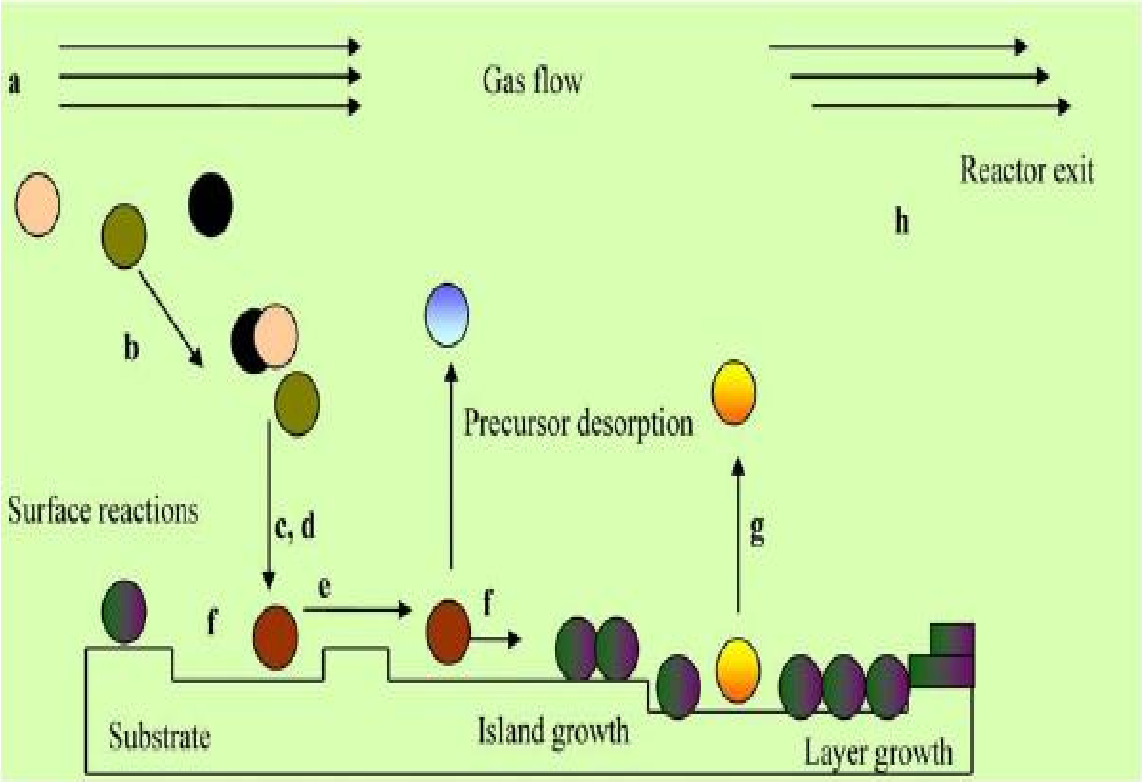

Fig. 2: Working principle of MOCVD process

WORKING PRINCIPLE OF MOCVD

MOCVD is a versatile and flexible chemical method for materials for depositing thin films of wide verity of materials for ceramic coatings and to fabricate semiconductor devices for IC technology. MOCVD process involves a few numbers of sequential steps starting from vapor- phase delivery to reactor, processing through a series of quasi state sub-process and concluding with the formation of solid thin film or powders in its final microstructure.

The sequence of MOCVD process is shown in figure (2) and individual sub-processes are described below-

1. SUPPLY OF PRECURSORS:

First, the single precursor of component is delivered to the reactor in vapor phase and then precursor vapors are transported up to the reaction zone by inert gases such as nitrogen or argon. The rate of vapor supply depends on velocity of the gases in reactor as well as the precursor concentration in carrier gas.

2. REACTION OCCURRING IN GAS PHASE:

The precursor molecules present in the reactor may interact with each other prior to deposition, thereby result in homogeneous nucleation and sometimes even in powder formation. Formation of particle in gas phase endangers the homogeneity of deposited films and hence phase reaction should be avoided.

3. DIFFUSION OF PRECURSORS MOLECULES TO THE SURFACE:

Transport near to the solid surface is always dominated by diffusion mechanism. When uniformly distributed diluted precursor vapors are forced over a flat substrate, a velocity profile developed averages with no net motion, that is, the velocity is zero adjacent to the substrate or surface of the reactor tube. The gaseous layer between substrate and the position where the velocity is maximum of the average velocity are called the boundary layer. Through the boundary layer precursor vapors are not available by the carrier gas flow but via diffusion through the layer to the substrate surface.

4. ADSORPTION OF PRECURSOR MOLECULES AT THE SURFACE:

The precursor molecules after diffusing through the boundary layer are adsorbed on the substrate surface. Usually the adsorbed reactants are assumed to be in equilibrium with the reactants in the gas phase.

5. SURFACE DIFFUSION OF ADSORBED SPECIES:

The adsorbed species undergo surface diffusion phenomenon and migrate prior to reaction.

6. PRECURSOR DECOMPOSITION OR SURFACE REACTION AT THE SURFACE AND FILM GROWTH ON THE SURFACE:

The adsorbed precursor molecules either react with their neighboring molecules or with the molecules present in the gas phase to form a film.

7. DESORPTION AND DIFFUSION OF REACTION OF THE REACTION BY-PRODUCTS:

The reaction by-products which are formed as a result of surface reactions, and which do not contribute in film formation, desorbs from the surface and diffuse out through the boundary layer. Similarly the unreacted precursor molecules also desorb and diffuse through the stagnant boundary layer. In order to avoid contamination of the film, the by-products need to be in the gaseous state.

8. REMOVAL OF BY-PRODUCTS:

Volatile by-products and the unreacted precursor molecules are pushed out from the reactor by bulk gas flowing in the reactor. Since MOCVD process occurs through a sequence of sub-process, the slowest sub-process is the overall rate-determining step.

CHOICE OF MOCVD PRECURSORS

An ideally good MOCVD precursor must possess following properties-

1. Appreciable volatility and molecular stability of vapor to avoid pre gas phase reaction or decomposition of vapors to achieve film growth at moderate deposition temperature.
2. Clean fragment action of organic matter at surface substrate during film growth.
3. Easily synthesized and purified in high yield at reduced cost, convenient during handling and transportation and possessing low degree of toxicity.
4. Adequate temperate window between precursor evaporation and decomposition to get high quality deposited preferably at lower surface temperature, which is generally required to prevent silicon based circuitry for microelectronic application.
5. Commendable compatibility with co-precursors in the case of multi Component ferroelectrics oxide film growth like PZT or BST.

Hence the goal of precursor engineering is to fine-tune the properties of compounds in order to optimize volatility, long-term stability, thermal decomposition window, reactivity against moistures and oxidants. There has been considerable effort towards the development of MOCVD precursor for gate application and four main precursor classes, based on the different legends system associated are identified. They are metal ß-diketonates, metal alkoxide, metal alkylamide and metal alkyls although a number of heteroleptic precursor containing mixed legand types. For example ß-diketons are bidentate chelating legend, which exhibits keto-enol tautomerismas shown in below;

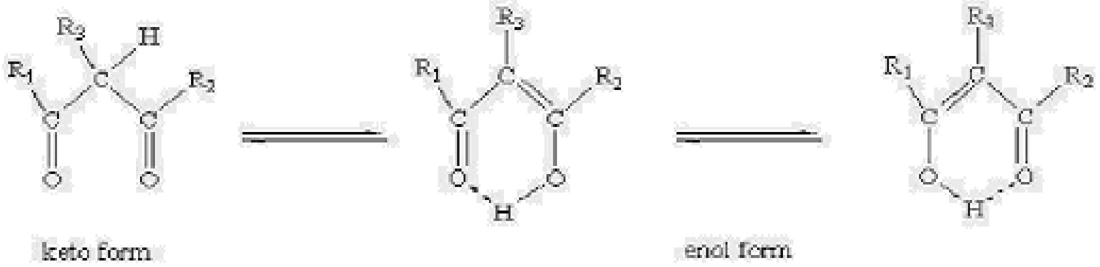

Fig. 3: ß-diketons

Physical and chemical properties of ß-diketonate legend can be tailored due to number of possible of metal. ß-diketonate complex has been used a potential molecular precursor for MOCVD applications, metal alkoxide is another common class of MOCVD precursors for metal oxide deposition. For the deposition of III-V semiconductor compounds such as GaAs, InAs etc the most commonly used precursor are trimethyl gallium (TMGa), trim ethyl aluminum (TM Al), trimethyl indium (TM In), trimethyl arsenic (TMAs) and hydride phosphine ($PH_{3)}$, arsine (ASH_3) typical reaction is;

$$(CH_3)_3Ga+ASH_3 \xrightarrow{600\text{-}800^{\circ}C} GaAS+3CH_4.$$

MOCVD REACTOR SYSTEM

The basic MOCVD reactor has components, which is describing below reactor components-

1. SUSCEPTOR:

A reactor is a chamber made of a material that does not react with the chemicals being used. It must also withstand high temperatures. This chamber is composed by reactor walls, liner, a susceptor, gas injection units and temperature control units. Usually, the reactor walls are made from stainless or quartz. To prevent over heating, cooling water must be flowing through the channels within the reactor walls. Special glasses, such as quartz or ceramic, are often used as the liner in the reactor chamber between the reactor wall and the subsector. A substrate sits on a "susceptor," which is at a controlled temperature. The subsector is made from a material resistant to the metal organic compounds used, graphite is sometimes used. For growing nitrides and related materials, a special coating on the graphite subsector is necessary to prevent corrosion by ammonia (NH_3) gas.

2. GAS INLET AND SWITCHING SYSTEM:

Gas is introduced via devices known as 'bubblers'. In a bubbler a carrier gas (usually nitrogen or or hydrogen) is bubbled through the metal organic liquid, which picks up some metalorganic vapor and transports it to the reactor. The amount of metal organic vapor transported depends on the rate of carrier gas flow and the bubbler temperature. Allowance must be made for saturated vapors.

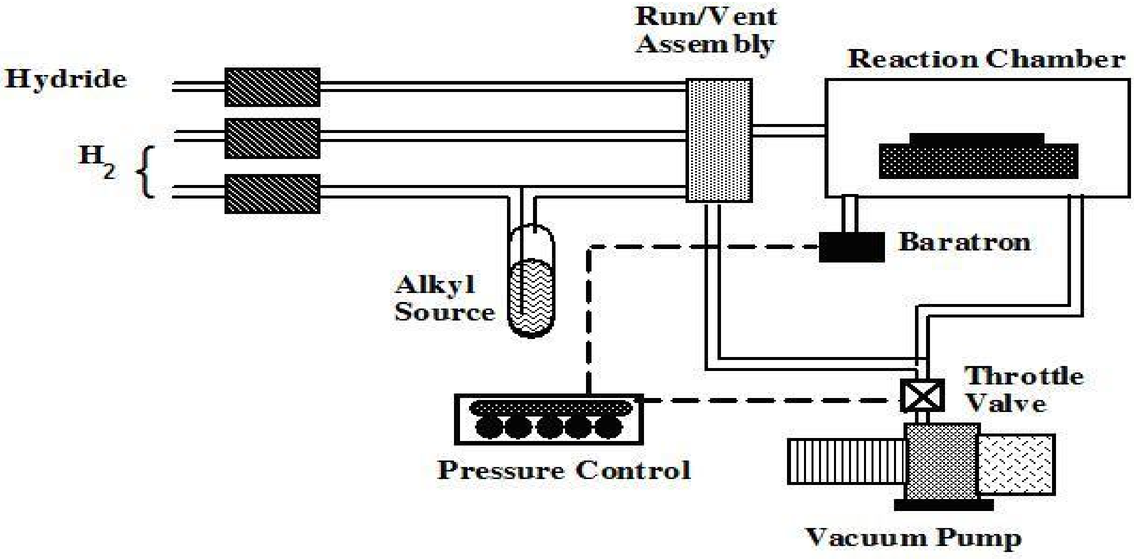

Fig. 4: MOCVD reactor

3. GAS EXHAUST AND CLEANING:

Toxic waste products must be converted to liquid or solid wastes for recycling (preferably) or disposal. Ideally processes will be designed to minimize the production of waste products.

ADVANTAGES OF MOCVD

MOCVD is a critical enabling technology, which is basically used for thin film deposition. It has several advantages such as;

1. Relatively easily installation of instrument.
2. Maintenance of equipment is low.
3. Availability of various sources such as growth of ternary, quaternary compound especially compound containing phosphors (P).
4. Excellent repeatability.
5. Low coast of ownership.
6. Uniformity of film thickness.
7. High film deposition rate.
8. Control over the stochimatery of the deposited material and sharp interfaces.
9. High volatility, high thermal stability obtains using MOCVD technology.
10. MOCVD offers selective growth, conformal step coverage and large-scale capability.
11. Most flexible.
12. High purity, abrupt interfaces, low interfacial recombination, simple reactor ect.

APPLICATION OF MOCVD

The equipment and chemical used in MOCVD are expensive and production cost is high, for that reason MOCVD is considerable most often used where very high quality and purity is required.

MOCVD is extensively used in wide area of applications in industry and research such as;

1. Double heterojunction structure design.
2. Quantum well, quantum dots design.
3. Large optical cavity lasers as well as bipolar field effect transistor.
4. In infrared detector, solar cell.
5. In growth of quantum modulation doped hetro structure and quantum wire.
6. In microelectronic application.
7. In solid-state laser design and light emitting diode.
8. In growth of high purity epitaxial film used for optics application.
9. In selective area growth (selective area growth (SAG) is specials form of epitaxy, in which a single crystal seed layer is converted by mask of material).
10. In advanced InGaN quantum well structure.

FUTURE SCOPE OF MOCVD

MOCVD technique has been widely employed in semiconductor industry for various thin films growth, which is one of the most critical steps in high technical micro fabrications. Using MOCVD we can build up many layers, each of a precisely controlled thickness, to create a material, which has specific optical and electrical properties. Using this technique it is possible to build a range of semiconductor photo detectors and layers. The equipment and chemicals used in MOCVD are expensive and production cost is high, for that reason MOCVD is considered most often where high quality is required. It has recently been investigated for other applications in area of very high temperature Oxidation protection up to 2200 ˚C.MOCVD has much futures scope in microwave and Opto-electronics applications, in advanced laser designs such as double heterostructures, quantum well and large Optical cavity lasers as well as bipolar, filed-effect transistors, infra-red detector and solar cells. In contrasts to these growth techniques, Nanotips can be grown using MOCVD at relatively low temperatures. These nanotips are of strong interest for applications such as field emission and near field microscopy. Growth of ZnO films on sapphire substrate by a MOCVD technique. These applications are used in light emitting diode to have high-energy efficiency. MOCVD has been established as very established fabrication process for deposition of high quality films.

CONCLUSION

In the present project we have described MOCVD growth technology of III-V, II-V semiconductor. MOCVD is widely used method for preparing epitaxial structures by depositing atoms on a wafer substrate. The undesired remnants are removed or deposited on the wall of reactor. MOCVD is currently among the most important techniques for growing thin, high purity epitaxial film with application in electronics and opto electronics. The desirable features of MOCVD process include thickness uniformity, high deposition rate, control over the stochiometry of the deposited material and sharp interfaces. MOCVD offers high throughput while retaining the other desirable properties thereby making it a very promising choice growth technology.

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