IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-6, Issue-7, July 2018 E-ISSN: 2347-2693

Analysis of Thin Films Applications and Deposition Processes

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Available online at: www.ijcseonline.org

Accepted: 20/Jul/2018, Published: 31/Jul/2018

Abstract- The numerous applications of modern surface and thin-film technology appear in all aspects of everyday life. They are necessary for products such as compact disks, solar cells, heat-protection glass, or in modern production systems, e.g. for machining. Although their process technology is costly, physical vacuum coating systems are common for producing functional thin films on an industrial scale. In order to appreciate thin film device applications, it is essential to understand what thin films are, what makes them so attractive for applications, and how they are prepared and characterized. This paper Analyze the brief review of salient and relevant features of the thin-films applications and thin-film deposition process.

***Keywords*:** Thin-films, Deposition, Applications, Physical& Chemical process.

I. Introduction

Material science and engineering community's ability to conceive the novel materials with extraordinary combination of chemical, physical and mechanical, properties has changed the modern society. There is a increasing technological progress. Modern technology requires thin films for different applications. Thin film technology is the basic of astounding development in solid state electronics. The usefulness of the optical properties of metal films, and scientific curiosity about the behavior of two-dimensional solids has been responsible for the immense interest in the study science and technology of the thin films. Thin film studies have directly or indirectly advanced many new areas of research in solid state physics and chemistry which are based on phenomena uniquely characteristic of the thickness, geometry, and structure of the film. The decrease in distance between the surfaces and their mutual interaction can result in the rise of completely new phenomena. Here the one dimension of the material is reduced to an order of several atomic layers which creates an intermediate system between macro systems and molecular systems, thus it provides us a method of investigation of the microphysical nature of various processes.

Thin films are especially appropriate for applications in microelectronics and integrated optics. However the physical properties of the films like electrical resistivity do not substantially differ from the properties of the bulk material. For a thin film the limit of thickness is considered between tenths of nanometer and several micrometers. Thin film materials are the key elements of continued technological advances made in the fields of optoelectronic, photonic, and magnetic devices. The processing of materials into thin films allows easy integration into various types of devices. The properties of material significantly differ when analysed in the form of thin films. Most of the functional materials are rather applied in thin film form due to their specific electrical, magnetic, optical properties or wear resistance. Thin film technologies make use of the fact that the properties can particularly be controlled by the thickness parameter. Thin films are formed mostly by deposition, either physical or chemical methods. Thin films, both crystalline and amorphous, have immense importance in the age of high technology. Few of them are: microelectronic devices, magnetic thin films in recording devices, magnetic sensors, gas sensor, A. R. coating, photoconductors, IR detectors, interference filters, solar cells, polarizer's, temperature controller in satellite, superconducting films, anticorrosive and decorative coatings.

II. Applications of Thin Films

Thin film materials have already been used in semiconductor devices, wireless communications, telecommunications, integrated circuits, rectifiers, transistors, solar cells, light-emitting diodes, photoconductors, light crystal displays, magneto-optic memories, audio and video systems, compact discs, electro-optic coatings, memories, multilayer capacitors, flat-panel displays, smart windows, computer chips, magneto-optic discs, lithography, micro electromechanical systems (MEMS), and multifunctional emerging coatings, as well as other emerging cutting technologies.

i) Optical Coatings

An optical coating is one or more thin layers of material deposited on an optical component such as a lens or mirror, which alters the way in which the optic reflects and transmits light. One type of optical coating is an antireflection coating, which reduces unwanted reflections from surfaces, and is commonly used on spectacle and photographic lenses. Another type is the high-reflector coating which can be used to produce mirrors which reflect greater than 99.99% of the light which falls on them. More complex optical coatings exhibit high reflection over some range of wavelengths, and anti-reflection over another range, allowing the production of dichroic thin-film optical filters.

ii) Photovoltaic

In the familiar rigid solar panel, the energy of incoming photons is converted to electricity in cells containing two thin layers of crystalline silicon. What makes roll-to-roll production of flexible film solar products possible is replacement of the crystalline silicon with amorphous silicon, supplied in high-solids slurries that can be deposited onto substrates by web-converting processes like slot die coating. Microlayer film, EDI can outfit its Contour cast film dies with a new system, based on technology licensed from 'The Dow Chemical Company', which makes it possible to produce film of standard thickness, yet with dozens of exceedingly thin 'micro-layers'. The multiple layer-to-layer interfaces create a torturous path for gas molecules and thus substantially increase the barrier properties of the film. This is critical for photovoltaic applications, which require barrier layers to prevent performance losses caused by infiltration of oxygen or moisture vapour.

Many in the solar power industry and the investment community, believe the arrival of grid parity, the point when cost of electricity generated by a rooftop photovoltaic (PV) cell system is equivalent to that purchased from an electrical utility will mark a major inflection point for the market that will deliver a huge increase in growth. However, even when true grid parity arrives, it's unlikely to generate an abrupt rise in solar system installations due to the high upfront costs and the long-term return of investing in a rooftop photovoltaic system, according to iSuppli Corp. In fact, growth is set to moderate during the years when grid parity arrives for various regions of the world as the industry enters a more mature phase.

iii) Semiconductor

Historically, the semiconductor industry has relied on flat, two-dimensional chips upon which to grow and etch the thin films of material that become electronic circuits for computers and other electronic devices. This thin layer (only a couple of hundred nanometers thick) can be transferred to glass, plastic or other flexible materials, opening a wide range of possibilities for flexible electronics. In addition, the semiconductor film can be flipped as it is transferred to its new substrate, making its other side available for more components. This doubles the possible number of devices that can be placed on the film. By repeating the process, layers of double-sided, thinfilm semiconductors can be stacked together, creating powerful, low-power, threedimensional electronic devices. "It's important to note that these are single-crystal films of strained silicon or silicon germanium. The strain is introduced in the way we form the membrane. Introducing strain changes the arrangement of atoms in the crystal such that we can achieve much faster device speed while consuming less power." For non-computer applications, flexible electronics are beginning to have significant impact. Solar cells, smart cards, radio frequency identification (RFID) tags, medical applications, and active-matrix flat panel displays could all benefit from the development. The techniques could allow flexible semiconductors to be embedded in fabric to create wearable electronics or computer monitors that roll up like a window shade. "This is potentially a paradigm shift. The ability to create fast, low-power, multilayer electronics has many exciting applications. Silicon germanium membranes are particularly interesting. Germanium has a much higher adsorption for light than silicon. By including the germanium without destroying the quality of the material, we can achieve devices with two to three orders of magnitude more sensitivity." That increased sensitivity could be applied to create superior low-light cameras, or smaller cameras with greater resolution.

iv) Photo Electrochemical Cells (PEC):

In photo electrochemical experiments, irradiation of an electrode with light that is absorbed by the electrode material causes the production of a current (a photocurrent). 50 The dependence of the photocurrent on wavelength, electrode potential, and solution composition provides information about the nature of the photo process, its energetic, and its kinetics. Photocurrents at electrodes can also arise because of photolytic processes occurring in the solution near the electrode surface. Photoelectrochemical studies are frequently carried out to obtain a better understanding of the nature of the electrode-solution interface. Photoelectrochemistry and Electrogenerated Chemiluminescence photocurrent can represent the conversion of light energy to electrical and chemical energy; such processes are also investigated for their potential practical applications. Since most of the studied photoelectrochemical reactions occur at semiconductor electrodes, we will review briefly the nature of semiconductors and their interfaces with solutions. Consideration of semiconductor electrodes also helps in gaining a microscopic understanding of electron-transfer processes at solid-solution interfaces.

v) Optoelectronic

An optoelectronic thin-film chip, comprising at least one radiation-emitting region in an active zone of a thin-film layer and a lens disposed downstream of the radiation-emitting region, said lens being formed by at least one partial region of the thin-film layer, the lateral extent of the lens being greater than the lateral extent of the radiation-emitting region. The thin-film layer is provided for example by a layer sequence which is deposited epitaxial on a growth substrate and from which the growth substrate is at least partly removed. That is to say that the thickness of the substrate is reduced. In other words, the substrate is thinned. It is furthermore possible for the entire growth substrate to be removed from the thin-film layer. The thin-film layer has at least one active zone suitable for generating electromagnetic radiation. The active zone may be provided for example by a layer or layer sequence which has a pn junction, a double heterostructure, a single quantum well structure or a multiple quantum well structure. Particularly preferably, the active zone has at least one radiation-emitting region. In this case, the radiation-emitting region is formed for example by a partial region of the active zone. Electromagnetic radiation is generated in said partial region of the active zone during operation of the optoelectronic thin-film chip.

vi) Flat Panel Displays

Developed from the Mykrolis contamination control technologies, Entegris provides a broad portfolio of liquid and gas contamination control technologies for the flat panel display fabrication. The Flat Panel Display (FPD) fabrication environment is among the world's most competitive and technologically complex. Device designers and manufacturers continually strive to satisfy the worldwide consumer's appetite for larger displays, greater pixel resolution and feature-rich performance – all at a lower cost than the previous generation of technology. The need to control contamination in air, gas and liquid process streams is now a paramount focus of process engineers and designers. Entegris provides the solutions to succeed under these extreme conditions.

vii) Data Storage

As the data storage density in cutting edge microelectronic devices continues to increase, the superparamagnetic effect poses a problem for magnetic data storage media. One strategy for overcoming this obstacle is the use of thermo-mechanical data storage technology. In this approach, data is written by a nano-scale mechanical probe as an indentation on a surface, read by a transducer built into the probe, and then erased by the application of heat. An example of such a device is the IBM millipede, which uses a polymer thin film as the data storage medium. It is also possible, however, to use other kinds of media for thermo-mechanical data storage, and in the following work, we explore the possibility of using thin film Ni-Ti shape memory alloy (SMA). Previous work has shown that nanometer-scale indentations made in marten site phase Ni-Ti SMA thin films recover substantially upon heating. Issues such as repeated thermo-mechanical cycling of indentations, indent proximity, and film thickness impact the practicability of this technique. While there are still problems to be solved, the experimental evidence and theoretical predictions show SMA thin films are an appropriate medium for thermo-mechanical data storage.

viii) Super Capacitor

Conventional capacitor stores energy electrostatically on two electrode separated by a dielectric, the capacitance of which is C= €A/d, where € being the dielectric constant, A surface area and d the dielectric thickness. In a double layer capacitor, charges accumulate at the boundary between electrode and electrolyte to form two charge layers with separation of several Angstroms. Super capacitors are electrochemical energy storage device. The away that super capacitor store energy is based in principal on two types capacitive behaviour the electrical double layer capacitance from the pure electrostatic charge accumulation at the electrode interface and the pseudo-capacitance developed from fast and reversible surface redox process at characteristic potential. Super capacitor integrated in to hybrid vehicle, power source, power control, multi source supply, fuel save etc.

ix) Gas Sensors

Advancements in micro technology and the evolution of new nonmaterial and devices have been playing a key role in the development of very accurate and reliable sensors. The technology of sensors has developed tremendously in the last few years owning many scientific achievements from various experiments, offering newer challenges and opportunity to the quest for every smaller devices capable of molecular level imaging and monitoring of pathological samples and the macromolecules has lately gained the focus of attention of the scientific community, particularly for remote monitoring due to the increasing need for environmental safety and health monitoring. Gas sensors generally operate different principles and various gas sensing elements have been developed have been past years, out of which resistive metal oxide sensors comprise a significant part. However these sensing elements typically operate at an elevated temperature for maximum performance. This makes higher power consumption which is not suitable for the inflation. Over the last decayed carbon nano-tube has attracted considerable attention, and great efforts have been made to exploit their unusual electronic and mechanical properties. These properties make them potential candidates for building blocks of active materials in nano-electronics, field emission devices, gas storage and gas sensors. Among these the room temperature gas sensing property is very attractive for many applications.

III. Thin Film Deposition Processes

The vast varieties of thin film materials, their deposition processing and fabrication techniques, spectroscopic characterization and optical characterization probes that are used to produce the devices. It is possible to classify these techniques in two ways. Physical Process, Chemical Process. Physical method covers the deposition techniques which depends on the evaporation or ejection of the material from a source, i.e. evaporation or sputtering, whereas chemical methods depend on physical properties.Structure-property relationships are the key features of such devices and basis of thin film technologies. Underlying the performance and economics of thin film components are the manufacturing techniques on a specific chemical reaction. Thus chemical reactions may depend on thermal effects, as in vapour phase deposition and thermal growth. However, in all these cases a definite chemical reaction is required to obtain the final film.

3.1 Physical Processes

3.1.1 Physical Vapour Deposition (PVD)

PVD processes proceed along the following sequence of steps: a) The solid material to be deposited is physically converted to vapour phase; b) The vapour phase is transported across a region of reduced pressure from the source to the substrate; c) The vapour condenses on the substrate to form the thin film. The conversion from solid to vapour phase is done through physical dislodgement of surface atoms by addition of heat in evaporation deposition or by momentum transfer in sputter deposition. The third category of PVD technique is the group of so called augmented energy techniques including ion, plasma or laser assisted depositions.

3.1.2 Evaporation

Evaporation or sublimation techniques are widely used for the preparation of thin layers. A very large number of materials can be evaporated and, if the evaporation is undertaken in vacuum system, the evaporation temperature will be very considerably reduced, the amount of impurities in the growing layer will be minimised. In order to evaporate materials in a vacuum, a vapour source is required that will support the evaporant and supply the heat of vaporisation while allowing the charge of evaporant to reach a temperature sufficiently high to produce the desired vapour pressure, and hence rate of evaporation, without reacting chemically with the evaporant. To avoid contamination of the evaporant and hence of growing film, the support material itself must have a negligible vapour pressure and dissociation temperature of the operating temperature.Laser beam evaporation has also come in to use recently. The laser source is situated outside the evaporation system and the beam penetrates through a window and is focused on to the evaporate material, which is usually fine powder.

3.1.3 Sputtering

If a surface of target material is bombarded with energetic particles, it is possible to cause ejection of the surface atom: this is the process known as sputtering. The ejected atoms can be condensed on to a substrate to form a thin film. This method has various advantages over normal evaporation techniques in which no container contamination will occur. It is also possible to deposit alloy films which retain the composition of the parent target material. DC sputtering, radio frequency sputtering and magnetron sputtering methods are the oldest types of sputtering used. High pressure oxygen sputtering and facing target sputtering are the two new methods for deposition of thin films for applications in superconducting and magnetic films.

3.1.4. Ion Plating

In this atomistic, essentially sputter-deposition process the substrate is subjected to a flux of high energy ions, sufficient to cause appreciable sputtering before and during film deposition. The advantages of physical methods are laid in dry processing, high purity and cleanliness, compatibility with semiconductor integrated circuit processing and epitaxial film growth. However, there are certain disadvantages such as slow deposition rates, difficult stoichiometry control, high temperature post deposition annealing often required for crystallization and high capital expenditure.

3.2 Chemical and Electrochemical Methods

Among chemical and electrochemical methods the most important are chemical vapour deposition, cathode electrolytic deposition, anodic oxidation and Chemical Bath Deposition

3.2.1.Chemical Vapour Deposition

Chemical vapour deposition can be defined as a material synthesis method in which the constituents of vapour phase react together to form a solid film at surface. The chemical reaction is an essential characteristic of this method; therefore, besides the control of the usual deposition process variables, the reactions of the reactants must be well understood. Various types of chemical reactions are utilised in CVD for the formation of solids are pyrolysis, reduction, oxidation, hydrolysis, synthetic chemical transport reaction etc.

3.2.2. Chemical Bath Deposition (Deposition by Chemical Reactions)

Thin films can be deposited by number of physical and chemical techniques and can be classified. The chemical methods are economical and easier than that of the physical methods. Physical methods are expensive but give relatively more reliable and more reproducible results. Most of the chemical methods are cost effective, but their full potential for obtaining devise quality films has not been fully explored. But there is no ideal method to prepare thin films, which will satisfy all possible requirements. Among the chemical methods, the electro-deposition technique (ED) is the most popular technique today because large number of conducting and semiconducting thin films can be prepared by this technique. Among the chemical methods of thin film depositions, Chemical Bath Deposition (CBD) is probably the most simplest method available for this purpose and it is also known as Chemical Solution Deposition (CSD) or Chemical Deposition (CD). The only requirements of these methods are a vessel to contain the solution (usually an aqueous solution of common chemicals) and the substrate on which deposition is to be carried out. In addition to this various complications such as some mechanism for stirring and a thermostated bath to maintain a specific and constant temperature are options that may be useful. Chemical deposition is the deposition of films on a solid substrate from a reaction occurring in a solution using the prototypical MS (metal sulphide) as an example, a M salt in solution can be converted to MS by adding sulphide ions (eg. H2S), MS immediately precipitates unless the solution is very dilute- a few milli molar or less in which case MS often forms as a colloidal solution. Another pathway for MS formation, one that does not require free sulphide ions, is decomposition of a MS-thiocomplex. In MS, the trick is to control the rate of these reactions so that they occur slowly enough to allow the MS either to form gradually on the substrate itself (at the early stages of deposition) or to the growing film, rather than aggregate in to larger particles in solution and precipitate out. This rate control can be accomplished by generating the sulphide slowly in the deposition solution. The rate of generation of sulphide, and therefore reaction, can be controlled through a number of parameters, in particular the concentration of sulphide forming precursor, solution temperature, and pH. Although CBD can be carried out both acidic and alkaline solutions, most of the CBD reactions have been carried out in alkaline solutions.

3.2.3 Basic Mechanism of Chemical Bath Deposition

In spite of the fact that CBD has been in use for a long time and that the reactions involved appear to be quite simple, the mechanism of the CBD process is often ambiguous There are several different mechanisms of CBD. These can be divided into four fundamentally different types. Deposition of Cdmium Sulphide is taken as an example.

The simple ion by ion mechanism:

$[Cd(NH_3)_4]^{2+}$ Cd^{2+} + $4NH_3$ (dissociation of complex to free Cd^{2+} ions) ------ (1)

$(NH_2)_2CS$ + $2OH^-$ S^{2-} + CN_2H_2 + $2H_2O$ (formation of sulphide ions) --(2)

Cd^{2+} + S^{2-} CdS (CdS fromation by ionic reaction) -------------- (3)

The simple cluster (hydroxide) mechanism:

nCd^{2+} + $2nOH$ $[Cd(OH)_2]_n$ (formation of a $Cd(OH)_2$ cluster) ------------ (4)

$[Cd(OH)_2]_n$ + nS^{2-} nCdS + 2nOH (exchange reaction) ------------- (5)

The complex decomposition ion - by - ion mechanism:

$(NH_2)_2CS$ + Cd^{2+} $[(NH_2)_2CS\text{-}Cd]^{2+}$ --------------- 6)

$[(NH_2)_2CS\text{-}Cd]^{2+}$ + $2OH^-$ CdS + CN_2H_2 + $2H_2O$ -------------- (7)

The complex decomposition cluster mechanism:

$[Cd(OH)_2]_n$ + $(NH_2)_2CS$ $[Cd(OH)_2]_{(n-1)}$ $(OH)_2Cd$------S-----C$(NH_2)_2$---------- (8)

$[Cd(OH)_2]_{(n-1)}$ $(OH)_2Cd$-----S----C$(NH_2)_2$ $[Cd(OH)_2]_{(n-1)}$ + CdS + CN_2H_2 + $2H_2O$ ------------ (9)

The last reaction continues until conversion of all the $Cd(OH)_2$ to CdS. The first two mechanisms involved free sulphide ions (or other anions). While the last two are based on breaking of a carbon-chalcogen bond and do not involve formation of free chalcogenide. Chemical reaction either takes place on the surface of the dipped substrate or in the solution itself, where a mixing of components on the surface to be coated is required. Most of the coatings are formed in a two step fashion; i) “Sensitizing” the surface for the nucleation reaction of the adhering coating layer. ii) Deposition of coating by selected reactions. The most widely used deposition methods are listed below A) Homogeneous chemical reduction of a metal ion solution by a reducing agent regardless the substrates. B) Electroless plating for the deposition of metallic coating by controlled chemical reduction that is catalysed by the metal or alloy being deposited. C) Conversion coatings forming a sacrificial layer containing compound of the metal substrate. D) Displacement deposition or galvanic deposition makes use of the electronegativity differences of metals. E) Arrested precipitation technique means a metal ion is arrested by organic complexing agent which is then made available by slow dissociation of the organometallic complex at specific pH value. Among the various chemical deposition systems, chemical bath deposition has attracted a great deal of attention because of its overriding advantages over the other conventional thin film deposition methods. The chemical bath deposition method for the preparation of thin films has recently been shown to be an attractive technique because of its simplicity, convenience, low cost and low temperature, and it has been successfully used for depositing ternary metal chalcogenide thin films. Understanding of the chemistry and physics of the various process involved in a deposition processes has now made possible to obtain undoped/doped, multicomponent semiconductor thin films of usual/unusual and metastable structure.

3.2.4 Selection of Deposition Process

No single technique is ideally suited for preparation of large area thin films with all the desired properties. Hence choice and selection of deposition process plays a vital role in the formation of good quality thin films, and while selecting a particular technique it should be tested satisfactorily for the following aspects: Cost effectiveness, It should be able to deposit desired material, Film microstructure and deposition rate should be controlled, Stoichiometry, should be maintained as that of the starting materials, Operation at reduced temperature,Adhesive at reduced temperature, Abundance of deposit materials, Scaling up of the process, Masking of the substrates, Control on film substrate interface and defects created in the film, Among the various techniques discussed above, arrested precipitation technique as well as electrodeposition technique used for synthesis of binary transition metal dichalcogenides and hybrid process of these two is employed in the synthesis of ternary mixed transition metal dichalcogenide in the present investigation.

IV. Conclusion

The thin film preparation for various applications, thin film deposition/growth has much importance. Generally in evaporation process, the solid material turns the vapour form during the material evaporation. The evaporated atoms acquires the kinetic energy, these adatoms may or may not be completely thermally equilibrated. When adatoms reaches the substrate, it moves horizontally over the substrate surface by jumping from one potential well to the other because of thermal activation from the surface and /or its own kinetic energy parallel to the surface. Thin film based photoelectrochemical (PEC) solar cells have wide applications due to their low fabrication cost, high throughput processing technique and ease of junction formation with the electrolyte. It is now well known that thin film solar energy conversion devices have become important and are eco-friendly, non-conventional alternative sources of energy. Photovoltaic conversion of solar energy is one of the most promising alternatives. The use of photovoltaic for direct conversion of solar energy into electrical energy is the need of present world.

References

[1]. Pushparaj V. L, Manikoth S. M., Kumar A., Murugesan S., Ci L., Vajtai R., Linhardt R. J., Nalamasu O., Ajayan P. M.."Flexible Nanocomposite Thin Film Energy Storage Devices". Proceedings of the NationalAcademy of Science USA 104, 13574-13577, 2007.Retrieved 2010-08-08.

[2]. Hu, L. C., J.; Yang, Y.; La Mantia, F.; Jeong, S.; Cui,Y. Highly Conductive Paper for Energy Storage. Proc. Natl. Acad. Sci.U.S.A. 2009, 106, 21490–21494.

[3]. Beyond Batteries: Storing Power in a Sheet of Paper". RPI. August 13, 2007. Retrieved 2008-01-15.

[4]. Paper battery offers future power". BBC News. August 14, 2007. Retrieved 2008-01-15

[5].Katherine Noyes. "Nanotubes Power Paper-Thin Battery". TechNewsWorld. Retrieved 2010-10

[6]Ng, S. H. W., J.; Guo, Z. P.; Chen, J.; Wang, G. X.;Liu, H. K. Single Wall Carbon Nanotube Paper asAnode for Lithium-Ion Battery. Electrochim. Acta 2005, 51, 23–28.

[7]Hu, L.; Hecht, D.; Gru¨ ner, G. Carbon Nanotube Thin Films: Fabrications, Properties, and Applications. Chem. Rev.2010, doi: 10.1021/cr9002962.