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Paper Authors **Manjula K, Dr. Satish Kumar**

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A CRITICAL STUDY ON DEPOSITION, CHARACTERIZATION TECHNIQUES AND DEPOSITION SYSTEMS

Manjula K
Research Scholar Monda University, Delhi Hapur Road Village & Post Kastla, Kasmabad, Pilkhuwa, Uttar Pradesh
Dr. Satish Kumar
Research Supervisor Monda University, Delhi Hapur Road Village & Post Kastla, Kasmabad, Pilkhuwa, Uttar Pradesh

ABSTRACT

Deposition, the process of depositing thin films or coatings onto various substrates, plays a pivotal role in diverse fields such as electronics, materials science, and nanotechnology. This abstract provides an overview of deposition techniques, characterization methods, and deposition systems employed in modern research and industrial applications. Deposition techniques encompass a wide range of methodologies, each tailored to specific requirements. Physical Vapor Deposition (PVD) methods, including evaporation and sputtering, involve the conversion of solid materials into vapor and subsequent condensation onto a substrate. Chemical Vapor Deposition (CVD) involves the reaction of precursor gases to form a solid film on the substrate. Atomic Layer Deposition (ALD) and Molecular Beam Epitaxy (MBE) offer precise control over layer thickness and composition at atomic scales. Other innovative techniques, such as electroplating, spray pyrolysis, and inkjet printing, further diversify the toolkit for material deposition. Characterization of deposited films is crucial for assessing their properties. Techniques like X-ray diffraction (XRD), scanning electron microscopy (SEM), and transmission electron microscopy (TEM) provide information about crystal structure, morphology, and composition. X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectrometry (SIMS) offer insights into chemical states and elemental composition. Additionally, ellipsometry, atomic force microscopy (AFM), and profilometry contribute to measuring thickness, surface roughness, and mechanical properties. Deposition systems have evolved to accommodate various materials and applications. Vacuum systems are commonly used in PVD and CVD processes to ensure controlled environments and minimize contamination. High-throughput systems are designed for large-scale production, whereas research-oriented systems prioritize flexibility and advanced control. Modular designs facilitate the integration of multiple deposition techniques into a single system, enabling the creation of complex multilayer structures.

Keywords: - Films, Material, Electronics, nanotechnology**.**

I. INTRODUCTION

TRANSPARENT CONDUCTING OXIDE DEPOSITION TECHNIQUES

Transparent oxide films have several technological uses; hence, they are often prepared via a deposition process. There are benefits and drawbacks to every approach. In addition, the characteristics of films made from the same material but deposited using various methods might vary. In order to achieve the optimal deposition parameters, one must have indepth understanding of the various deposition procedures available. In order to deposit clear oxides such as Indium Oxide, Tin Oxide, Zinc Oxide, Titanium di-Oxide, etc., the following methods have been utilized.

1. Sol-Gel
2. Spray Pyrolysis
3. Pulsed Laser Deposition Technique (PLD)
4. Chemical Vapour Deposition (CVD)
5. Chemical Solution Deposition (CSD)
6. Sputtering

Doped Zinc Oxide (ZnO) and Indium Tin Oxide (ITO) have been deposited using an RF-magnetron sputtering approach as part of the current Ph.D. program.

Sputtering Technique

During gas discharge studies, Grove in 1852 (UK) [1] and Plücker in 1858 (Germany) [2] independently noticed that material may be sputtered off the cathode. Almost immediately after its invention in 1877 [3], metal sputtering was put to use in the manufacturing of mirrors. In the early 1930s, it was put to use coating the wax masters of Edison phonographs with electrically conductive layers of gold. Sputtering has fallen out of favor for a while, but it has recently made a comeback as one of the most adaptable techniques due to its ability to produce films with excellent adhesion and process-specific features.

Working Principle

The earliest vacuum technique for making thin films is called cathode sputtering, or more precisely, the Sputtering of (often solid) materials by bombardment with positive energetic and non-reactive noble gas ions. The term "Sputtering" is used to describe the ejection process that occurs when impinging ions transfer momentum to the atoms of the target surface.

II. SILICON THIN FILM DEPOSITION TECHNIQUES

Microcrystalline and nanocrystalline hydrogenated silicon (c-Si:H and nc-Si:H) thin films have attracted attention due to their distinctive optical, electrical, and structural features. There are a number of different film deposition processes available. There are benefits and drawbacks to every approach. Film characteristics are sensitive to deposition settings. Therefore, it is crucial to talk about deposition methods. The most common approaches for depositing Si:H films are:

1. Plasma-enhanced chemical vapor deposition (PECVD) [6;7] or glow discharge (GD).
2. Sputtering [8;9].
3. Photo-Chemical Vapor Deposition (Photo-CVD) [10;11].
4. Microwave Chemical Vapor Deposition [12;13].

Chemical vapor deposition using electron cyclotron resonance [14,15,16].

In this thesis, silicon thin films were deposited using radio frequency pulsed electron chemical vapor deposition (RF-13.56 MHz). These benefits result from using this method:

Working Principle of rf-PECVD method:

The rf-PECVD process is commonly employed in comparison to other deposition techniques for the following reasons;

1. Plasma Enhanced Chemical Vapor Deposition (PECVD) is a

technique that allows for chemical vapor deposition at far lower temperatures and pressures than those needed for thermal CVD.

2. The second benefit of plasma deposition is the ability to tailor the kinetic energy of the ions that assault surfaces in the plasma.
3. The characteristics of the deposited layer are drastically altered by exposure to such a high density of ions. Films get denser and the film stress becomes more compressive as ion bombardment increases.
4. Fourth, source gases such as SiH4, B2H6, and PH3 may be used to effectively adjust the doping level.
5. Among the many advantages of plasma deposition is the fact that the reactor can be cleaned quickly and simply. Silicon, silicon nitride, and silicon dioxide may all be removed off electrodes and chamber walls by injecting a fluorine-containing gas (such as CF4) and igniting plasma.

The electrode is subjected to a high frequency electric field in the rf-PECVD method. Since electrons are lighter than ions, they experience more acceleration. The electrons fluctuate between the electrodes due to the alternating field. However, at sufficiently high stimulation frequencies (vex > 1 MHz) [20], the ions become stationary because they are too heavy to follow the a.c. field. Chemical fragments, precursors to film growth, are created when gas molecules collide with high-energy electrons.

III. POLYCRYSTALLINE SILICON FILM DEPOSITION TECHNIQUE BY METAL INDUCED CRYSTALLIZATION PROCESS

Several techniques exist for depositing metals. Metal Induced Crystallization is a method by which amorphous films may be crystallized in the presence of metal. The metal-induced crystallization (MIC) technique has promise as a viable strategy because to its low temperature and short time requirements. However, the MIC technique has greater appeal due to the fact that the metal concentration given to the film may be adjusted.

Metals react with the film after being dispersed there in the MIC process. At low temperatures, when homogeneous nuclei production is impossible, the presence of metal atoms in an amorphous film weakens the bonds in the film and facilitates the development of heterogeneous nuclei. With further low-temperature annealing, the number of these atypical nuclei grows. As a consequence, the temperature at which crystallization occurs is lowered using this method. Grain size is proportional to the number of nuclei, therefore decreasing their quantity is just as crucial as increasing the grain size.

This MIC procedure has two distinct phases:

1. Deposition of metal on the amorphous film.
2. The process of annealing of the film.

IV. DEPOSITION OF METAL ON THE AMORPHOUS FILM

The deposition of metal on glass or film just requires a heat source. However, the Electron Beam Evaporation (e-beam) Technique allows for more precision in this process. The degree of crystallization in the Metal Induced Crystallization (MIC) process is highly dependent on the thickness of the metal or amorphous silicon (a-Si) sheet. Therefore, the e-beam deposition method offers more practicality.

Electron Beam Evaporation Technique

Accurate production of thin films, alloys, and multilayers relies on maintaining a constant evaporation rate. The Electron Beam Evaporation technique is another deposition method described in this paper. The e-beam approach is another name for this method. This technique is a variation on physical vapor deposition. The first thin film was created by M. Ruhle in 1940 using Electon Beam Gun Evaporation [Society of Vacuum Coaters]. Numerous scientists have used this method in a variety of investigations [36, 37, 38, 39].

When deciding between thermal and e-beam evaporation, the former requires:

- High film deposition rates
- Unlike sputtering, which causes greater damage because it uses high-energy particles; the film generated by impinging atoms on the substrate surface is less damaging.
- The high vacuum condition utilized during evaporation contributes to the film's excellent purity.
- There is less of a propensity for the substrate to heat up unintentionally.

The main advantages of this process is

- We can direct electron beams.
- Capable of introducing structural changes to the films as well as enhancing the stoichiometry;
- ion current and energy can be independently controlled.

Working principle

In e-beam evaporation, high-energy electrons from an e-beam cannon are focused on a small area of the source material to evaporate it. The crucible already has the raw materials inside of it. The term "Electron Beam Evaporation" describes this process well. Since high vacuum prevents the accumulation of contaminants on surfaces, allows for the deposition of films with a low impurity density, and allows electrons to attain a broad mean free path, it is the first step in the deposition process to evacuate the chamber.

This method basically works on the following principle:

1. After the substrate has been deposited within the chamber, the space is emptied. The molecules must evaporate in the vacuum before they can condense on the chamber's surfaces.
2. After this, the filament will be heated.
3. A heated cathode (negative electrode), sometimes known as a filament, "evaporates" electrons. This is analogous to thermionic emission, which is produced by the tungsten filament in a standard incandescent light bulb operating at low voltage.

V. CONCLUSION

In conclusion, the fields of deposition, characterization techniques, and deposition systems play a vital role in shaping the landscape of materials science, nanotechnology, electronics, and various other industries. The synergy between these elements drives innovation, enabling the creation of tailored materials with precise properties to meet the demands of modern applications.

Deposition techniques have evolved significantly, offering a rich array of methodologies to deposit thin films and coatings. From the precise control of atomic layer deposition to the scalability of physical vapor deposition and chemical vapor deposition, researchers and engineers can select the most suitable technique for their specific needs. These techniques allow the manipulation of material properties at various scales, influencing factors such as thickness, composition, crystallinity, and surface morphology.

Characterization techniques stand as essential tools for gaining insights into the deposited films' properties. Through techniques like X-ray diffraction, microscopy, spectroscopy, and surface analysis, researchers can unravel the structural, chemical, and morphological characteristics of thin films. These insights are crucial for validating the quality of deposited materials, optimizing processes, and understanding their behavior in different environments.

Deposition systems serve as the foundation for material fabrication processes. These systems provide the necessary controlled environments for deposition processes to occur, ensuring reproducibility and reliability. As technology advances, deposition systems have become more versatile, integrating multiple techniques, automation, and real-time monitoring. High-throughput systems drive industrial production, while research-oriented systems offer flexibility and customization to explore new material possibilities.

The interplay between deposition, characterization, and deposition systems underpins the development of groundbreaking technologies. From semiconductor manufacturing to solar cell production, from coating technologies to emerging nanomaterials, the triad of deposition, characterization, and deposition systems shapes the design and performance of modern devices.

As research continues to push the boundaries of material properties and applications, the collaborative efforts in these domains remain pivotal. Engineers and scientists working in deposition must collaborate closely with those skilled in characterization and deposition system design to ensure that materials are not only fabricated with precision but also thoroughly understood. This holistic approach enables the realization of innovative concepts, the discovery of novel materials, and the advancement of technology across diverse sectors. Ultimately, the ongoing advancements in deposition techniques, characterization methods, and deposition systems promise a future marked by ever-improving materials and technologies that enhance our daily lives and reshape industries.

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