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A STUDY OF RF SPUTTERING TECHNIQUE AND CONDITIONS FOR DEPOSITING $MgIn_2O_4$ FILMS

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ABSTRACT

Recent developments in engineering have given thin film technology a prominent place at the forefront of the technical development of tomorrow's civilization. Substrate patterning, under-bump metallurgy, thin film filters and optical coatings for fiber optic telecommunication systems, high-speed machining and grinding, solid lubrication and heat dissipation, and bio-active coatings for medical implants are just some of the many fields that have benefited from these developments. One of the most important emerging technologies is nanotechnology, to which thin film technology is intrinsically linked. New generation manufacturing and precise engineering will rely heavily on bulk materials and coatings that are nano composite, nano phase, or nano structure. Precision engineering relies heavily on thin film coating, and its importance will only grow as nanotechnology advances. Optoelectronics, microelectronics, and other areas of contemporary technology rely heavily on thin films. Surfaces and the thin coatings that cover them have been studied for quite some time. However, it has lately gained prominence in a number of academic disciplines. Since 1930, researchers have made significant strides in the field of thin-film surface physics. Films typically range in thickness from 0.1 nm to 300 nm and need good adhesion to the surface, chemical stability, uniformity, purity, and a low defect density. Deposition or creation of extremely thin films (of the order of micrometres or less) of various materials on a silicon wafer (or other appropriate substrate) may be accomplished using a variety of methods. Then, utilizing photolithographic methods and appropriate etching procedures, these films may be patterned. Silicon dioxide (oxide), silicon nitride, polycrystalline silicon, and aluminum are all examples of frequently used materials.

KEYWORDS: RF Sputtering Technique, MgIn2O4 Films, thin film technology, telecommunication systems

INTRODUCTION

Thin films may be deposited from a variety of materials, including precious metals like gold. Electrochromic materials respond to a voltage pulse by temporarily altering their optical characteristics in a manner that can be reversed. Current applications for these materials include displays, rearview mirrors, and smart windows. The many properties of thin film nucleation and growth are largely to blame for this. Thin film growth methods enable considerable versatility, allowing the manufacture of two- or three-dimensional structures with the appropriate geometrical, topographical, physical, crystallographic, and metallurgical properties. These characteristics are being used more and more to adapt the structure to the physical, mechanical, chemical, and electrochemical characteristics of micro materials.

There are six critical phases to the thin film deposition process:

1. Absorption-surface-generated atoms and molecules 1.
2. Two, these particles must first diffuse for a while before they can become a part of the thin film.
3. The included species react with one another and the surface to produce the film's bonds, which is step three of the incorporation process.
4. Nucleation refers to the first clusters of film material to form.
5. The film's structure or morphology changes from amorphous to polycrystalline to single crystal as its thickness increases.
6. Diffusion occurs inside the bulk of the film and between the film and the substrate in step six. Precision engineering relies heavily on film coating, which will play an increasingly crucial role in the development of nanotechnology.

When comparing thin-film and thick-film technologies, the key difference is that in the former case, molecules are deposited whereas in the later case, particles are deposited.

APPLICATIONS OF THIN FILMS

Microelectronics, communications, optoelectronics, integrated optics, photovoltaic devices, and waveguides all rely heavily on advances in thin film science and technology. Nowadays, thin film devices like those used in windows, mirrors, rechargeable Li ion batteries, and space applications are indispensable [1, 2]. "Thin film" refers to any substance with a thin thickness that was formed by a condensation process involving atoms, molecules, ions, or clusters of species. It is possible to create "thick film" materials by applying a liquid or paste on top of a substrate. A thin film device's main benefit is the little amount of resources it consumes and the minimal space it takes up. If you live in a warm environment, you can keep your building from becoming too hot by installing energy-efficient windows that have a coating that is clear to visible light but reflective in the near IR range [3].

VARIOUS THIN FILM PREPARATION TECHNIQUES

Metals, semiconductors, insulators, dielectrics, etc. may all be used to create thin films, and many different methods have been devised to facilitate their creation. In addition, novel techniques are being developed to enhance the quality of the deposits by achieving the highest possible reproducibility in their attributes and the lowest possible variance in their compositions [4].

Both physical vapor deposition and chemical vapor deposition fall under the umbrella term "thin film deposition." Physical techniques include vacuum evaporation and sputtering, in which the material to be deposited is first converted to a gaseous form by evaporation or an impact process, and then deposited. Chemical techniques include gas-phase technologies like light CVD and plasma-enhanced CVD in addition to more traditional chemical vapor deposition. The substrate itself serves as the raw material for the oxide in the chemical thin film process known as thermal oxidation. Electrolytic deposition, electroless deposition, electrolytic anodization, spray pyrolysis, and liquid phase epitaxy are all examples of liquid phase chemical processes. Molecular beam epitaxy (MBE) is a high-tech evaporation process that takes place in an extremely tight vacuum and under precise supervision. In addition to the aforementioned physical ways of film deposition, there are other methods based on the use of an ion or ionized cluster source. When depositing compound films, reactive deposition employs a reactive component [5]. However, there are a number of criteria that influence the decision of which preparative process to use, including the melting point of the charge, its stability, the purity and features sought of deposits, etc. [6]. Therefore, MIO film deposition may be accomplished in a number of ways. However, DC/RF magnetron sputtering, pulsed laser deposition, and spray pyrolysis are the most often reported and commonly utilized methods in industry. Maisel and Glang[7] and Chopra[8] provide excellent descriptions of the different thin film preparation methods. This research paper describes the process of making MIO films using RF-magnetron sputtering in great depth. Each deposition method and its regulating parameters will produce films with unique properties since MIO's properties are so sensitive to the material's microstructure, stoichiometry, and the presence of impurities.

1. Pulsed laser deposition

Metals, semiconductors, insulators, dielectrics, etc. may all be used to create thin films, and many different methods have been devised to facilitate their creation. In addition, novel techniques are being developed to enhance the quality of the deposits by achieving the highest possible reproducibility in their attributes and the lowest possible variance in their compositions [4].

2. Magnetron Sputtering

(Cathode) sputtering refers to the process by which atoms are ejected off a surface and subjected to the bombardment of positive ions, which are typically inert. Ejecting atoms and forcing them to condense on a substrate is known as thin film deposition.

Penning invented magnetron sputtering, a method of sputtering that makes use of a magnetic field to improve sputtering efficiency. In a basic planar magnetic system, the cathode is flat, and the field lines from the permanent magnets behind it trace a closed loop around the cathode's surface, creating a toroidal field. To prevent the substrate from heating up by itself, the secondary electrons created become stuck in cycloidal orbits close to the target. Magnetron sputtering systems are able to operate at significantly lower pressures and lower target voltages than are achievable for RF diode sputtering due to the confinement of the plasma and the resulting intense plasma. The rates of deposition are also rather high and spread across wide regions. Because of the minimal substrate heating, many different substrates may be used. Thin films of MgIn2O4 have been produced using the sputtering method by a number of researchers.

3. Spray Pyrolysis

Spray deposition of thin films is a straightforward process that can cover enormous regions with little outlay. The film is not on the solution itself, as is the case with other chemical solution deposition methods, but rather on a separate substrate. After being sprayed over a hot substrate, the solution forms a film by a pyrolytic or hydrolytic chemical reaction of the liquid droplets. Both conventional sprayers and ultrasonic nozzle sprayers, which use compressed argon gas as a carrier gas, have been put to use. An aqueous solution comprising soluble salts in a proper ratio of component elements is sprayed over heated surfaces to initiate spray pyrolysis. There is an endothermic interaction between the sprayed droplets and the substrate. The substrate's heat kickstarts the chemical reaction by supplying the thermal energy required to break down the reacting materials into their component parts and then recombine them to produce the oxide films of interest. Other byproducts and solvents that are volatile may leave the process in the vapour phase.

SPUTTERING

The collisions between the atoms of the solid surface and the energetic particles erode the surface and remove the atoms from the surface. The term "sputter" or "sputtering" describes this phenomenon.

Grove made the first discovery of sputtering more than 130 years ago. A gas discharge tube's cathode and grid may be destroyed by sputter, which was formerly only seen as an undesirable drift effect.

Cleaning and etching surfaces, depositing thin films, analyzing surfaces and surfaces layers, and creating sputter ions are only some of the many modern uses for sputtering [26].

Sputtering may be caused by a variety of energetic particles, including ions, neutral atoms, neutrons, electrons, photons, and so on.

1. Basic Concept of Sputtering

Multiple ion interactions with the surface of the material (the target) might be anticipated during an ion bombardment.

1. To begin with, the incoming ions are reflected, where they are then neutralized.
2. the target will release a secondary electron as a result of the ion's collision.
3. the target is where the ion is buried. Ion implantation describes this process.
4. the target material undergoes certain structural rearrangements due to the ion collision.
5. The ion impact initiates a chain reaction of collisions between target atoms, which may result in the ejection of one of the target atoms. Sputtering describes this occurrence.

The 100eV to 100keV energy range of incident ions is where sputtering occurs most often. Ion implantation takes the lead at higher energies.

2. Mechanism of Sputtering

Initially, two theoretical theories were offered to explain sputtering.

1. there is the hypothesis of thermal vaporization, which states that the surface of the target gets heated to the point of vaporization as a result of being hit by energetic ions.
2. The momentum-transfer hypothesis proposes that the kinetic moments of incident particles are transferred to the atoms of the target's surface, resulting in emission.

3. Advantages of Sputtering Technique over other Techniques

The benefits of magnetron sputtering are as listed.

1. Reasonably cool substrates (even at room temperature) are used.
2. Films that adhere well to their substrates.

3. a high rate of deposit (up to 12 m min-1).
4. The films have excellent thickness uniformity and a high density.
5. The procedure is stable over time and is easy to regulate.
6. Easily sputtered alloys and compounds may include elements with widely varying vapor pressures.
7. Numerous compounds may be deposited from elemental (metallic) targets using reactive sputtering in rare/reactive gas combinations. 7.
8. Low-cost deposition alternative.
9. Nine, it may be expanded to cover vast areas (up to 3x6 m2).

4. Sputtering system

Thin film deposition using sputtering is one of the potential methods. The dc diode sputtering system is the most fundamental kind of sputtering apparatus. In contrast to dc diode sputtering, the other sputtering technologies represent advancements on that front.

THIN-FILM NUCLEATION

Substrate contact to the incident vapor results in the formation of several tiny, highly mobile islands or clusters. During this time, the island density quickly saturates, and the previous nuclei expand in size as they absorb impinging atoms and subcritical clusters. The next step is for the islands to merge, creating a more continuous surface area, a phenomena that may take on a liquid-like quality at elevated substrate temperatures. Coalescence reduces island density, allowing for localized denuding of the substrate and subsequent nucleation. In many cases, crystallographic faces and orientations are maintained on islands and at the interfaces of coalesced particles that were previously randomly orientated. A linked network with empty channels in between develops as coalescence proceeds. As more material is laid down, the channels narrow and close up, leaving behind solitary holes. In the end, the gaps too are filled in, and the film may be considered continuous. The initial few hundred angstroms of film thickness may be attributed to this chain of events, which takes place during the early phases of deposition.

Many observations of future film production indicate to the three primary growth types depicted schematically as island (or Volmer-Weber), layer (or Frank Van der Merwe), and Stranski Krastanov. The smallest stable clusters on the substrate nucleate and expand in three dimensions to create islands, a process known as island growth. This occurs when the bonds between atoms or molecules in the deposit are stronger than those to the substrate. Initially, islands are formed when metal and semiconductor films are placed on oxide substrates. During layer expansion, the opposite behaviors are seen. In this case, the smallest stable nucleus expands primarily in two dimensions, leading to the development of flat sheets. In this phase of development, atomic bonds to the substrate are stronger than those to neighboring atoms. A second, looserly bonded monolayer is then laid on top of the first full monolayer. The layer development mode is maintained as long as the bonding energy is steadily reduced toward the bulk-crystal value. The Stranski-Krastano (S-K) development mechanism combines the layer and island growth modes to produce an intermediate form. When this happens, islands arise because further layer growth is undesirable after one or more monolayers have formed.

The S-K mode of film growth has been seen often in both metal-metal and metal-semiconductor systems.

CONCLUSION

Radio frequency (RF) magnetron sputtering to create thin films of MgIn2O4. The films were characterized by XRD, EDS, XPS, SEM, AFM, optical, thermal, and electrical measurements over a wide range of deposition conditions. In this paper, we analyzed and methodically reported on all prominent aspects. MgIn2O4 thin film's sensitivity and stability as an ethanol sensor were investigated. The RF power was adjusted from 50W to 200W while the MgIn2O4 thin films were deposited onto the warmed glass substrates. To further investigate the physical and chemical characteristics of the films and to improve the deposition conditions for creating the device grade films, the substrate temperature was adjusted from ambient to 250°C. The optimal deposition conditions were used to generate stoichiometric MgIn2O4 thin films. The films' electrical and optical characteristics were used to fine-tune the deposition conditions. MgIn2O4 thin films with good orientation and device quality were created in our lab using the RF magnetron sputtering method under optimum deposition circumstances. The following are the best deposition conditions for producing films with the desired characteristics of uniformity, homogeneity, and good adhesion.

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