COMPARATIVE STUDY OF ALUMINIUM DOPED ZINC OXIDE FOR ORGANIC LIGHT-EMITTING DIODES (OLED)

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RESEARCH COMPLETION CERTIFICATE

It is certified that **Ms. Maha Javed** of BS (session 2018-2022), Department of Physics has carried out research work entitled **“Comparative study of Aluminium doped Zinc Oxide for Organic Light-Emitting Diodes (OLED)”** under my supervision.

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ABSTRACT

Technology has a significant impact on the electronics industry, causing it to become more creative and innovative in its production. Organic light-emitting diodes, or OLEDs, have transformed modern technology. We have studied that Aluminum doped zinc oxide tin coatings or thin films were produced by sputtering at various radio frequency power densities under argon gas pressure of 0.15 Pascal (Pa) to improve parameters at all for utilization for both in bottom emitting and transparent organic light emitting diodes. Therefore, the films have a wurtzite type hexagonal arrangement with 0002 preferential orientations and an optical transparency of more than 80 percent in the visible range, however the energy bandgap varies. Sputtering at a high radio frequency power density of 2.47 Wcm^{-2} produces Aluminium doped zinc oxide films with low resistivity and high work function, which are suitable for anodes in bottom emitting organic light emitting diodes. Al- doped ZnO films developed at a low radio frequency power density of 0.31 Wcm^{-2}, on the other hand, relate to a low work function with somewhat greater electrical resistivity and are therefore suitable for cathode in transparent organic LEDs. Hence, the equivalent performance of organic light emitting diodes made with Al-doped Zinc oxide and Indium tin oxide anodes confirms Aluminium doped zinc oxide applicability as an alternative electrode. We have studied that sol-gel method was used to create graded patterns of aluminum-doped zinc oxide or the AZO multilayered thin coating or thinner films on quartz glass substrate. To minimize stress, different Aluminium mol percent doped Zinc oxide graded topologies of multilayered thin films were developed. The tension between the layers was minimized by using graded multilayered thin films. X-ray diffraction abbreviated as XRD and an Ultraviolet visible spectrophotometer have been used to explore and analyze the graded constructions of multilayered Aluminium doped zinc oxide thin coatings or thin films. As a result, multilayered graded thin films of the thin coatings may be generated with less stress then crystallized or stabilized all along the c-axis. Thus, the optical transmittance of the films is about 94.8 percent at 400 nanometers to 800 nanometers wavelength and the energy band-gap is approximately 3.27 electron-volts. The sol-gel method has important implications for creating trustworthy aluminium doped zinc oxide multilayer nanostructures or the thin film coatings with minimal strain-stress for device applications such as OLEDs. The sol-gel method was considered to be the most promising and appropriate method for the synthesis of Al-doped ZnO for device applications such as OLEDs.

COMPARATIVE STUDY OF ALUMINIUM DOPED ZINC OXIDE FOR ORGANIC LIGHT-EMITTING DIODES (OLEDS)

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LIST OF ABBREVIATIONS

LCD	Light Crystal Display
LED	Light Emitting Diode
OLEDs	Organic Light Emitting Diodes
CRT	Cathode-ray tube
HIL	Hole Injection Layer
HTL	Hole Transport Layer
BL	Blocking layer
UV	Ultraviolet
ZnO	Zinc Oxide
Al	Aluminium
eV	Electron-volts
ALD	Atomic Layer Deposition
AZO	Aluminium doped zinc oxide
RF	Radio Frequency
ITO	Indium tin oxide
XPS	X-ray photoelectron spectroscopy
PL	Photoluminescence
CBD	Chemical Bath Deposition
XRD	X-ray diffraction
TCO	Transport Conducting Oxide
PES	Polyester sulfone

UV-Vis	Ultraviolet visible
DPEMOCVD	dual plasma enhanced metal organic chemical vapor deposition

CHAPTER 1

INTRODUCTION

1.1 Electronics Industry

The electronics industry is a business that deals with the development of new product designs and then marketing those products. These gadgets include radio equipment, television sets, sound systems, desktops, electronic components, circuitry, and microelectronics. Electronics industry not only transformed factories, offices, and homes, but it also grew to be a significant financial sector as well as commercial that rivalled the different sectors and industries. In terms of size, steel making, the synthetic chemical, and automotive sectors are the most significant. [1].

Therefore, extensive application of microelectronics has resulted in an increase in numerous kinds of goods in the electronics industry, including applications to other areas of the economy [2].

Figure 1.1 Progress in Electronic Industry [1].

The microelectronics technology industry is advancing at a rapid pace, resulting in constant technical impact and change. High-level manufacturing, high-level product integration, reliability, improved product performance, an increased number of goods created, and lower device manufacturing costs are some of the significant advances in product manufacturing that can be witnessed. Microelectronics technology is the field that allows for the fabrication of numerous gadgets. Demand for low-cost goods with high performing features drives innovation [2].

Microelectronics Industry (A branch of electronics technology known as microelectronics is the research, configuration, and manufacturing process of minute electronic components that use a small amount of electric power), because ICs are such small designs, adding additional functionalities to a design becomes much easier. The electronics industry is using this technology to create electronic devices that are as tiny as a wristwatch but have computing capabilities built in.

Flexible devices, wearable technology, wireless charging, smart lighting, LCD displays, and encapsulation technologies are just a few of the devices that have emerged as a result of the growing use of microelectronics. Technology has a significant impact on the electronics industry, causing it to become more creative and innovative in its production [2].

1.2 Display Technology (LED)

The alteration of display technology is a good example of how microelectronics can be used. Image displays are now sharper, thinner, and of higher quality than they were in the past, thanks to advances in microelectronics [2].

Figure 1.2 Innovation of Display Technology [2].

Light-emitting diode abbreviated as LED demonstration is a type of display that routines a frame of LEDs as a well-lit source. Currently, a large emergence of microelectronic devices practices LED displays by means of both a screen and a standard for user-system interaction. Smartphones, TVs, tablets, computers, laptop screens, and some other electronic devices in the modern era all have LED displays as their output [3].

1.3 Organic Light-Emitting Diode Characteristics (OLED)

Organic matter has gotten a lot of attention in optical and electrical device applications like sustainably sourced circuitry, photovoltaic panels, and organic light emitting equipment. One of the most essential approaches for exhibition and illuminating purposes is indeed the organic light emitting diode which is abbreviated as OLED. OLED has many advantages, including self-emission, a great viewing angle, a dynamic response, a simple configuration, and a low driving wattage. The design and manufacturing conditions for OLED technology seem to be very comparable to those for Liquid crystal display. The device, which would be made of a large glass substrate, serves as a planar light source. When compared to LCD technology, OLED is indeed a self-emissive display that does not require a separate backlight unit, simplifying the process flow. OLED configuration is ideal for adaptable photo-electronic device components because it is a low-temperature operation. Just at heart of OLED is the organic material, and also the configuration management. If the organic matter remains constant, the optoelectronic density of OLEDs can be changed by varying the layer thickness, which is determined by constructive or destructive interference. [4].

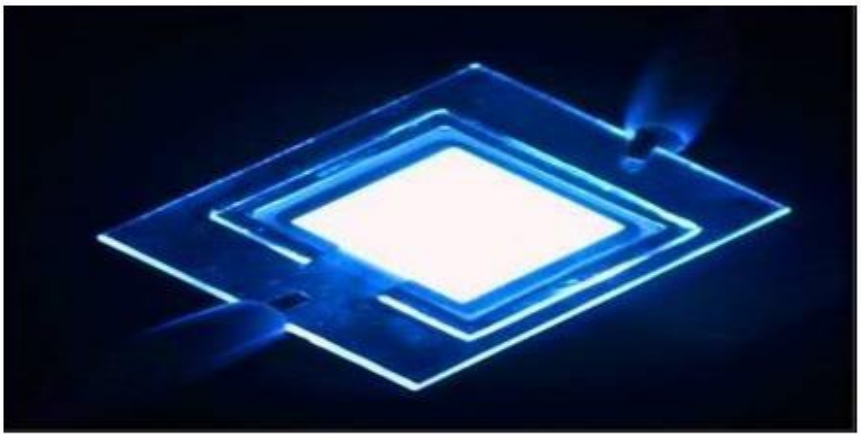


Figure 1.3 Light-Emitting Diode (OLED) [4].

1.4 The Most Important Differences Between LED and OLED

1. An LED display's illumination is provided by a backlight, which is essentially a light emitting diode. In contrast, because carbon is being used as an organic material

that serves as a natural source of light, OLED does not require a backlight to provide illumination.

2. An OLED display has a wider viewing angle of about 84 degrees than an LED display, which has a viewing angle of about 54 degrees.

When viewed from the center, an LED display provides excellent picture quality; however, as we move to either side of the center, the picture quality deteriorates.

3. In terms of brightness, LED displays outperform OLED displays. Using quantum dots, which improves backlight quality, increases LED brightness significantly.

Forcing an OLED to operate at maximum brightness for an extended period of time, on the other hand, can shorten its life.

4. Compared to LCD screens, LED screens allow for a thinner display. When comparing OLED to LED, however, OLED allows for a thinner screen.

5. LED response time is slower than OLED response time. In comparison to LED diodes, the diodes in an OLED system react much faster.

6. LED displays have a larger screen size of around 100 inches compared to OLED, which has a screen size of around 90 inches following recent advancements.

7. OLED uses less energy to operate than LED because it is self-illuminating and does not require a backlight.

8. Screen burn-in is a problem with CRT, plasma, and OLED displays, as the LED display does not exhibit this effect. Whenever the screen that forms the image degrades over time, burn-in occurs.

9. OLEDs are also flexible and bendable, which means they can be used not only in televisions but also in the future in the creative space of smart devices. When combined with OLED's thin characteristics, the screen can indeed be made as thin as a piece of paper and bent and folded at will, something that was previously unthinkable in the LED era.

OLED (organic light-emitting diode) is a type of LED that is made up of organic semiconductor material. Although the working principles of the two are nearly identical, various parameters distinguish them [5].

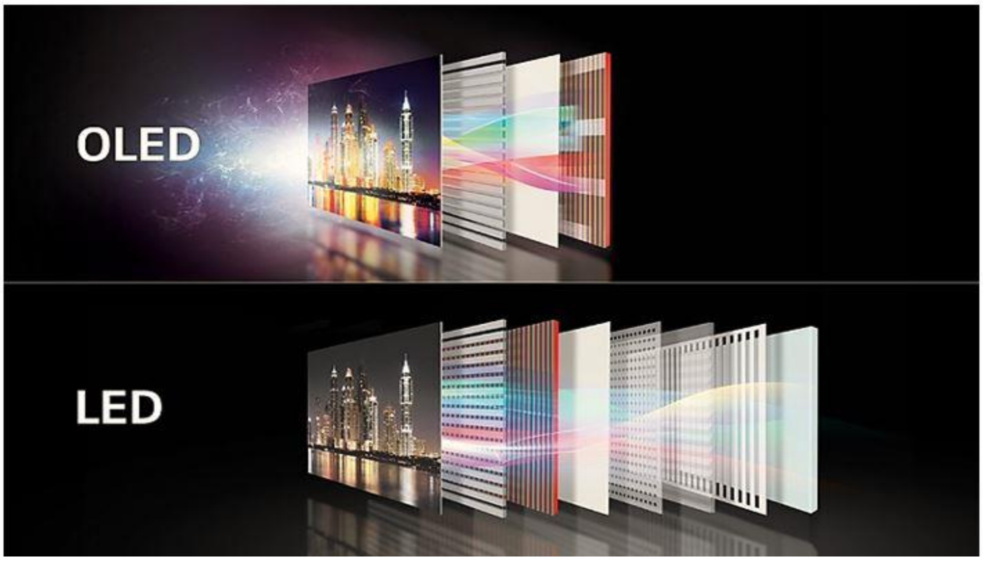


Figure 1.4 Difference between LED and OLED screen [6].

1.5 OLED cell structure in its most basic form

Organic light emitting diodes abbreviated as OLEDs are the solid state monolithic devices created by depositing a thin coating sandwiched among two thin-film thermally conductive electrodes. Hence, w When an electric current has been given to an organic LEDs the electrical charges such as electrons and holes, flow from the electrodes into the thin films and reappear in the particle emitter zone to generate excitons. Once excitons, or excited states, have been formed, they loosen up to a lower energy level by sending pulses of light or undesired heat.

An OLED cell has a basic structure which consists of a layer of thin organic layers wedged here between highly conductive anode and a conducting cathode. So the following is a diagram of an OLED structure:

- The foundation of OLED is the substrate which can be glass or metal foil.
- The positively charged anode, which can be transparent or opaque depending on the kind of organic light emitting diode injects holes into the organic layers that make up the organic LEDs device.
- A layer known as the Hole Injection Layer abbreviated as HIL is mounted on the top of the anode and accepts holes from the anode before attempting to inject them thus far into the gadget or device.

- The Hole Transport Layer abbreviated as HTL permits holes to pass through and subsequently meet the emissive layer.

The emissive layer which is the heart of the device and light source that is made up of the colour scheme transmitter semiconducting together into host and is also the layer that turns energy into light.

- A blocking layer abbreviated as BL is a barrier or layer that limits electrons that are the charge carriers to the emissive layer in order to improve OLED technology.
- A layer named as Electron Transport Layer which is abbreviated as ETL allows electrons to travel across it to reach the emissive layer.
- Cathode that is transparent or impenetrable and depending upon the type of organic LEDs that is negatively charged in order to inject electrons through into organic layers that therefore help cover the organic light emitting diodes or the OLEDs device [7].

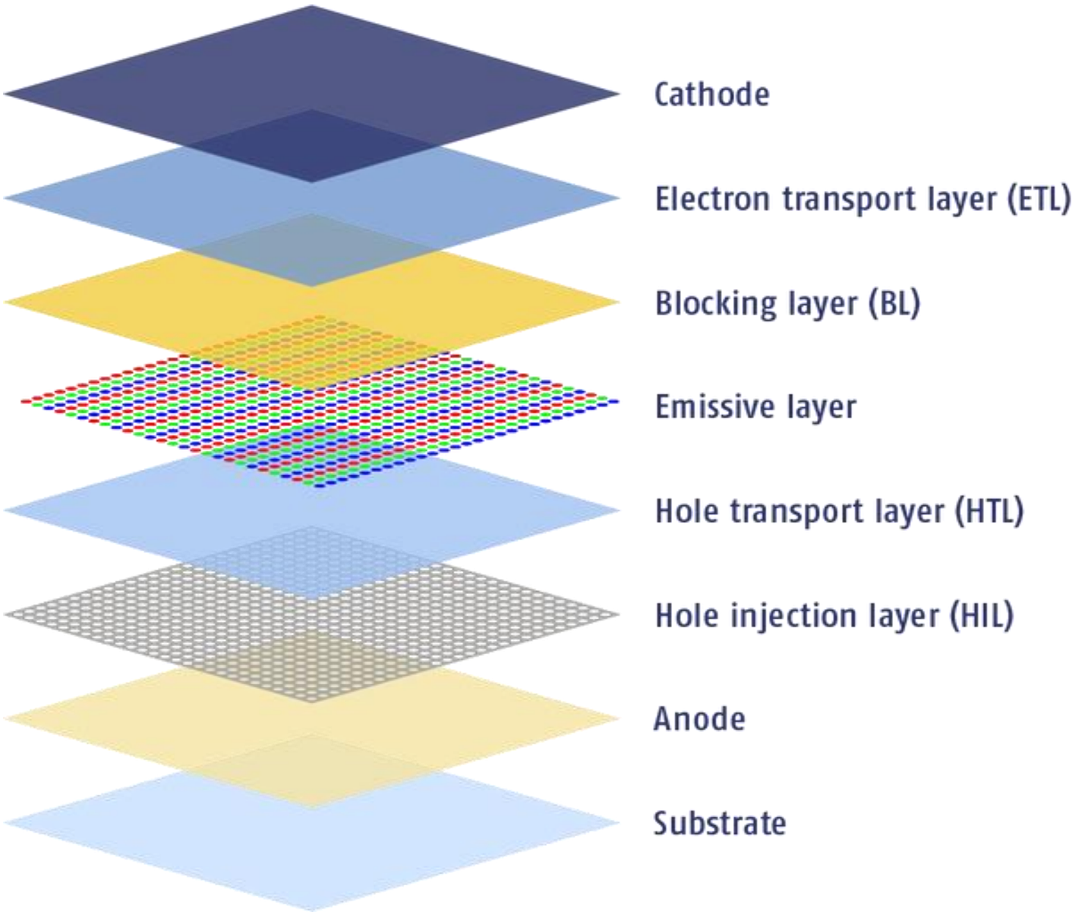


Figure 1.5 The Structure of a Basic OLED Cell [7].

1.6 OLED Display Applications

The OLED presentations are commonly found in digital strategies like as televisions with high-definition resolution, processor displays, and portable devices for example Android smartphones, streaming devices, image sensors, portable gaming consoles, and mini-screens. This application necessitates a high level of readability and reliability. OLEDS are the best alternative because they use less energy and produce more light, high-definition display Color fidelity, high efficiency, and operation stability are some of the outstanding features of current OLED technology [8].

1.6.1 Flexible display

A flexible display, also known as a rollable display, is an electronic visual depiction that is easily adaptable, as opposed to the old flat screen displays found in most digital equipment. In recent years, several consumer electronics manufacturers have expressed interest in incorporating this screen technology in to other e-readers, smartphones, and other electronic goods. Of that kind panels can be folded like a page without misrepresenting the picture or text. Some of the technologies used to create a rollable display are automated ink, ethically sourced LCD, and Organic light - emitting (OLEDs) [9].

Figure 1.6 OLED display that bends [10].

1.7 Wide Band Semiconductor

Wide bandgap semiconductors have several advantages:

1. Because of their large band gap energy, semiconductors have numerous advantages in optical and electrical technology and wearable applications.

2. The one broad gap energy is acceptable as it can be used in photodetectors to absorb or emit ultraviolet (UV) light.

3. In visible region, these are transparent. [11]

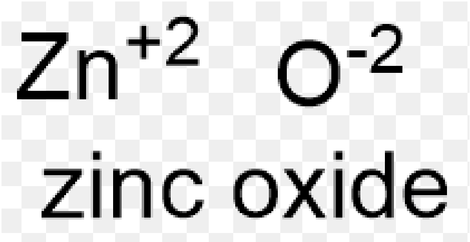
4. The ability to grow at low temperatures.

5. In a wide band gap, there is a high concentration of n-type carriers.

6. Materials with an extensive or wide band gap play a significant part now in UV light optical absorption and emission [11].

1.8 Zinc Oxide (ZnO)

Zinc Oxide abbreviated as ZnO has a wide band gap of 3.4 electron volts which relates to ultra-violet (UV) emission, when combined with a high mobility of 200 cm3. Aluminium doped Zinc Oxide (ZnO) is a thermally stable Aluminium source that is highly insoluble. Thermal conductivity of ZnO is extremely high. The large free excitation binding energy of ZnO allows for efficient excitonic emission at room temperature, which is a significant advantage. Electricity cannot pass through oxide compounds. Thermal conductivity of ZnO is extremely high [12].



Zn^{+2} O^{-2}

zinc oxide

Figure 1.7 ZnO [12].

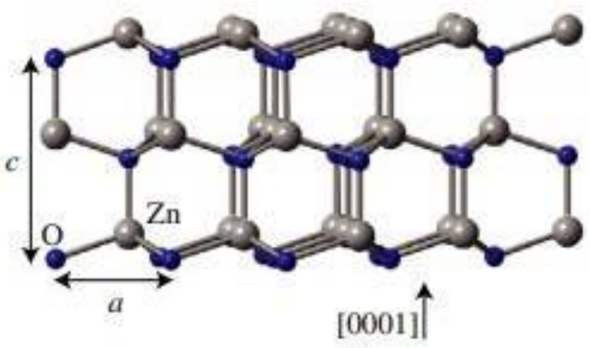


Figure 1.8 Wurtzite crystal structure of ZnO with lattice parameters a and c [13].

1.8.1 Structure

At room temperature, ZnO is a direct wide band gap semiconductor with band gap energy which is EG = 3.37 eV with a large exciton binding energy of 60 meV, allowing for efficient excitonic emission. It is visible-wavelength transparent and suitable for UV and blue-wavelength optoelectronic devices. This means Zn^{+2} and an anion of O^{-2} combine to form this molecule. It has two possible structures: hexagonal and cubic, but hexagonal structures are more likely to appear. Strain or doping can change the lattice parameters [14].

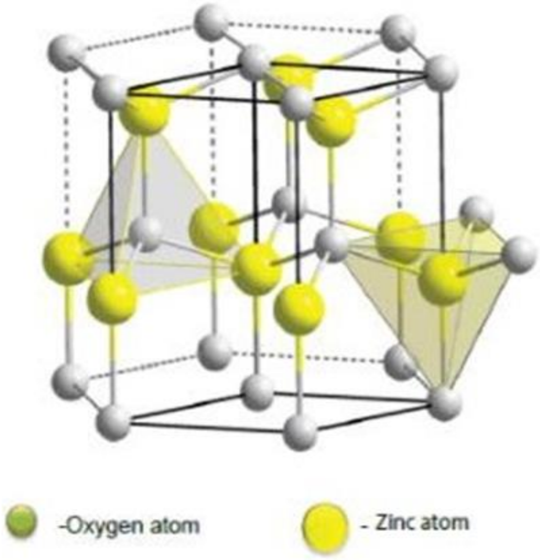


Figure 1.9 Crystal structure of ZnO [14].

1.9 Aluminium (Al)

Aluminium is a chemical element with symbol Al and the atomic number 13. Aluminium's density is around one-third that of steel and it is lower than that of other common metals. When exposed to air, it has a strong affinity for oxygen and forms an oxide layer on the surface. Aluminium has a silver-like color and reflectivity. It is nonmagnetic and bendable or flexible as well as ductile. Aluminum only has one stable isotope which be present as 27Al, which itself is extremely abundant, trying to make it the universe's twelfth most abundant element. [15].

Thermal and electrical electrical resistivity:

Aluminum is an extremely good heat and electricity conductor nearly twice as good as copper in weight and a s a result, aluminium has emerged as the most suitable material for significant power transmission systems. This is also a great heat sink for such a diverse array of application areas that needs immediate dissipation of heat, the same as desktop circuit boards and LED lights [16].

Material which is aluminiun is an absolutely superb emitter of visible light and heat and this, combined with its light weight, tends to make it a best as possible for reflective surfaces in light fixtures and rescue comforters, for instance. Cool roofs manufactured of coated aluminium are highly valuable in greatly lowering solar heat inside a house even though they reflect up to 95 percent of sunlight. [16].

Figure 1.10 Aluminium Metal [16].

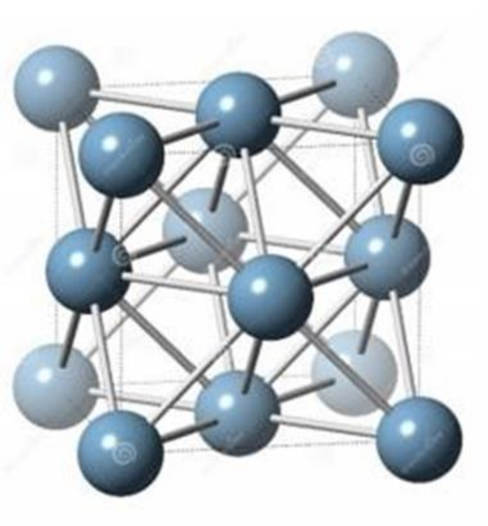


Figure 1.11 Crystal structure of Al [17].

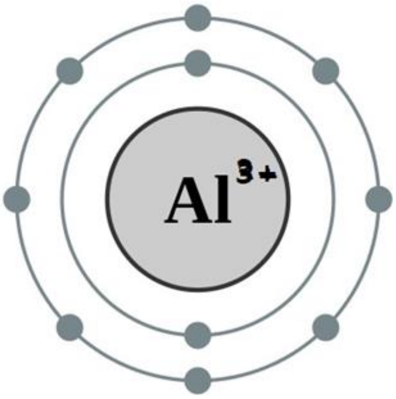


Figure 1.12 Atomic Structure of Al [18].

1.10 Doping

Doping is the introduction of an impurity into a semiconductor to alter its electrical, chemical, or magnetic properties. There are two ways to dope:

- Intrinsic

It's a kind of doping wherein the impurity decided to add to the substance is identical to the doped substance (semiconductor). This type of substance is referred to as a pure semiconductor because it does not change its electrical properties due to the presence of other impurities [19].

- Extrinsic

It is the kind of doping in which the impurity is made of a different semiconductor material and alters the intrinsic semiconductor material's properties by changing the electron and hole ratio concentration [19].

1.11 Alters in the Synthesis of ZnO Thin Films as an Outcome of Al Doping

In Aluminium doped zinc oxide coatings or films, the atomic layer deposition methodology or the ALD method is being used to develop new functional, optoelectronic, and electronic properties. Whenever the Al doping level is higher the diffraction peaks shift from (002) to (100) suggesting that now the ZnO film growth mode shifts. Spectroscopic ellipsometry was used to measure the texture, thickness, and band gap of ZnO films as well as optical constants. Vastly increased carrier concentration after Al doping provokes a blue shift in bandgap and also in absorption edge which is translated by the Burstein Moss effect. With different doping concentrations, the carrier concentration and resistivity vary dramatically and the optimal values is found. Property modifications and enhancements are crucial for just using Al doped ZnO films as transparent conductors in a wide range of applications. The Atomic Layer Deposition abbreviated as ALD is a fantastic deposition technique that uses self-limiting surface chemical reactions to start creating incredibly uniform and smooth films with accurate thickness regulation [20].

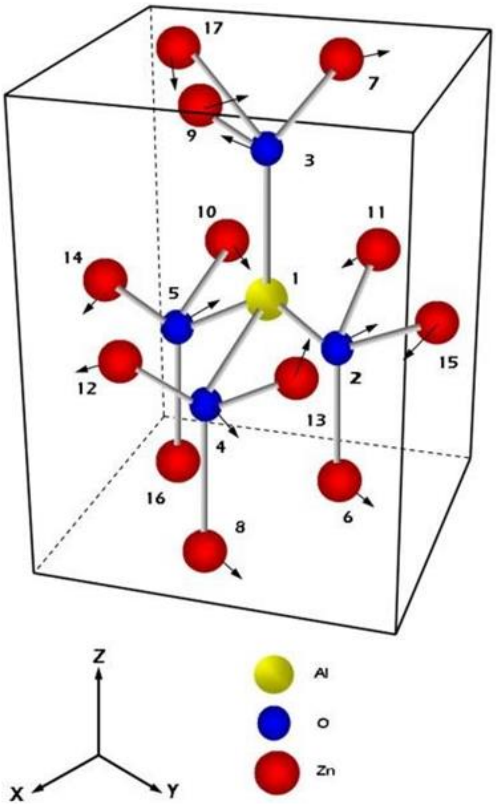


Figure 1.13 Al Doped ZnO [20].

1.12 Sol-gel Method

Ceramic materials are created by trying to settle which is nm-sized colloidal solution particles onto such a pre-existing surface. The favored solid particles for instance metal alkoxides are dissolved in a solution in an attempt to establish a ‘sol,' which is spun, immersed or covered onto such a substrate, as well as transferred to a mould. Polymerization of the particles in the sol happens via partial evaporation of the solvent or the extension of an initiator that resulting in the 'gel,' which is then heated to a high temperature to yield the final quality product [21].

1.13 Radio Frequency (RF) Sputtering

Radio Frequency Sputtering abbreviated as RF is a technique which involves interchanging the electrical potential of a current at radio frequencies in a vacuum environment to help stop a charge from building up on some types of sputtering base material that over time can outcome in arcing into the plasma, spewing particles causing quality problems on thin films or even going to lead to the total removal of atom sputtering results in terminating the process [22].

RATIONALE

Organic Light Emitting Diodes abbreviated as OLEDs are indeed a comparatively recent display or screen technology that is currently advancing at a rapid pace and these organic light emitting diodes or OLEDs are used to create what else are regarded as the world's greatest display screens. Organic Light Emitting Diodes (OLEDs) emerged as a very promising flat-panel display technology because of their lots of advantages and therefore, many possibilities remain open for the discovery of new materials as well as the development of new methods that might improve organic light emitting diodes or OLEDs displays even more. Perhaps the goal of this research is to develop adjustable imaging systems or the important display technologies that employ organic LEDs or OLEDs which are being gaining popularity due to their lightweight, durable profile, capability to bend, curve, roll and fold for transportation, and ultimate technical design flexibility. The main goal is to focus on the improved performance of OLEDs for the purpose to meet the future demands of electronic industry.

OBJECTIVES

Following are the objectives of this study:

- To study comparative analysis of Al doped ZnO for OLEDs
- To highlight the advantages of growing Al doped ZnO films via sol-gel process for flexible OLEDs that plays important role to fulfil future needs of electronic industry.
- To determine that the transparent conducting Aluminium doped Zinc Oxide thin films produced by radio frequency sputtering method can be used as anodes for bottom emitting OLEDs as well as cathode for transparent organic LEDs instead of ITO (Indium tin oxide).
- Synthesis of Al doped ZnO for OLEDs devices in the development and innovation of display technology.

CHAPTER 2

LITERATURE REVIEW

B.M. Chaya et al. (2021) investigated the effect of different anode materials being substituted for conventional indium tin oxide (ITO) anodes. The comprehensive simulation has been carried out at 540 nm on an organic light-emitting diode comprised entirely of widely used emissive or organic layers to tris (8-hydroxyquinoline) aluminum alloy (Alq3). Different device simulations with different work functions are modelled and simulated using aluminium zinc oxide as AZO, graphene which is 7 nm/12 nm, zinc mono-oxide ZnO, and silver (Ag) anode materials. The finite difference domain abbreviated as FDTD method has been used to measure the light transmission of OLEDs. The directional dispersion of OLEDs with varying anodes in connection to viewing angle is reported. As a consequence, the results reveal that the visual effects using electrode materials including Nanomaterials such as graphene have a greater enhancement in luminous flux or the light output when they are compared to other sources. To assess the alternative option to indium tin oxide electrode materials, the far field contours of all anode materials that improve light production and optimum transmission from an organic light emitting diode are illustrated in this study [23].

L.G. Daza et al. (2021) used the RF reactive magnetron sputtering technique to grow high-quality reasonably uniform and homogeneous thin films of vertical Aluminium doped zinc oxide nanorods on preheated soda lime glass slides while also simultaneously rotating the substrate. They used a fresh and novel system which allows them to control the angle pace and frequency growth parameters (f). These characteristics in optoelectronic devices could've been orchestrated using motion pictures with transmittances significantly larger than 80% and adjustable bandgap energy systems tend to range from 3.47 electron volts - 3.62 electron volts and also the respective refractive index values ranging from 1.77 to 2.11 at 700 nm. The films structural properties demonstrated that they have been highly crystalline as well as predominantly grow in the (002) plane direction. The growths achieved with just this particular the combination of the surface twist motion frequency and maintained rotation are an effective process for the making AZO thin films to excellent structural and optical properties at room temperature [24].

Changyeong Jeong et al. (2021) employed inefficient traditional waveguide mode decoupling approaches using organic light-emitting diodes abbreviated as OLEDs which improve fabrication originality. And the t transparent anodes devoid of indium tin oxide or ITO improved efficiency while exhibiting no influence on some other device properties or the device parameters. The researchers employed an ultra-thin silver or Ag film as either a transparent electrode and performed a comprehensive parametric investigation of organic light emitting diodes, discovering that waveguide modes may be completely erased via tailoring an organic LED layout just under the cutoff point thickness or texture of waveguide modes. Waveguide mode withdrawal in organic waveguides has been experimentally proven using index-matching fluid and a prism. The negative permittivity, extremely thin thickness, and highly conductive properties of a uniform copper-seeded Ag film can suppress waveguide mode formation, enhancing external quantum efficiency while maintaining any other OLED character traits as well as paving the way for intensively developed organic LEDs in contemporary advanced screen sector [25].

Yong Wu et al. (2020) used atomic layer deposition (ALD) to deposit low-temperature Aluminium Doped Zinc Oxide which is Al doped ZnO thin films and the properties of Aluminium fixing level and then also the temperature of substrate on the structural and optical, electrical properties of AZO thin films have been studied in this review. This research work indicates a good potential temperature such as low temperature deposition of Al doped ZnO thin films as transparent conductive oxide film that can be well enough with flexible, low temperature packaged optoelectronic devices for instance solar cells which is photovoltaic cells and more particularly for OLED [26].

Ramchandra Pode et al. (2020) studied flexible plastic-based OLED lighting devices that offered the benefit of aesthetically pleasing energy-efficient systems. The homogeneity, flexibility, structure conformability, various form factors, ultra-high, and transparent features of adaptable OLED lighting encourage creative solutions, latest design liberty, and a slew of endless opportunities. In the near future, OLED technologies are expected to become more widespread in automobiles particularly in tail lights. In actuality, adjustable OLEDs are starting to open up a world of new of lighting possibilities. OLED lighting and on the other hand, is still very much in initial stages and requires even more development. Lowering panel costs and working to improve durability and resilience in severe situations could boost the acceptability of OLED lighting solutions, monetizing the technology. White OLEDs, particularly flexible OLEDs, have the potential to change the fate of light sources, markets, industries [27].

Liting Zhang et al. (2020) used an adaptively coupled plasma abbreviated as ACP system to examine the etching properties of aluminum-doped zinc oxide thin films. Changes in the Cl2/Ar gas equivalency ratio, RF power, and DC reference voltage were used to examine the dry etching characterizations of Aluminium doped zinc oxide materials. The greatest etching rate of AZO sheets in Cl2/Ar plasma is 70.45 nm. Optical emission spectrometry or the OES was used to determine the ion configuration of Cl2/Ar plasma. X-ray photoelectron spectroscopy abbreviated as XPS was used to analyze the chemical alteration on the outside of Aluminium doped ZnO films [28].

Yu-Tong Cao et al. (2019) created Al-doped ZnO or the AZO nanowires, nanotubes, nanoplane-cone nanoparticles, and nanomaterials. AZO nanowires' structural, photoluminescence abbreviated as PL and field emission abbreviated as the FE characteristics have all been studied. The ultraviolet emission was caused by near band edge emission and whereas the peak in the visible light area was caused by deep-level emission, according to the PL measurements. AZO nanowires also emit more ultraviolet light than other types of samples. A femtosecond Z-scan method was also used to study the nonlinear absorption characteristics of Aluminium doped zinc oxide nanowires. The form effect on the nonlinear optical absorption capacities of Aluminium doped ZnO nanowires was investigated. The Aluminium doped zinc oxide nanotubes or the nanowires exhibit reverse saturable absorption abbreviated as RSA behavior, according to the findings. Our findings suggest that AZO films might be useful in additional optoelectronic applications [29].

Y. C. Su et al. (2018) investigated atomic layer deposition-prepared aluminum-doped zinc oxide (AZO) layers. At visible and near-infrared wavelengths, the obtained layers have a high optical transmittance. Optimal AZO growth compositions with the highest electrical conductivity are found by ranging the Al content. Based on the research findings of optical and electrical measurements selected AZO films with the highest conductivity are employed as transparent electrodes in LCD panel systems. These devices exhibit electro-optical modulation properties similar to commercial ITO electrode devices [30].

Mahdiyar Nauri Rezaie et al. (2018) revealed that CBD is one of the most efficient, effective, and safe solution-based methodologies by establishing a low-temperature wet chemical bath deposition (CBD) method. This technique is presently routinely designed to make ZnO NRs. A seed layer is frequently deposited on the substrates in this CBC approach. The impact of initiation stage and seed layer on the physical attributes of as-grown ZnO NRs was researched in a research. According with research, the seed layer appears to have a considerable influence on the alignment and pace of development of ZnO NRs. Finally, the charge carrier transport mechanisms of manufactured UV-OLEDs have been investigated systematically [31].

R. K. Pandey et al. (2018) deposited Al doped ZnO thin films of varied thickness on silicon (Si) substrates using the sol-gel spin coating process. Thermally annealed films' structural, surface morphology, optical characteristics and vibrational properties are examined. At ambient temperature, the x-ray diffraction abbreviated as XRD patterns demonstrated a polycrystalline hexagonal wurtzite structure containing compressive stress. The surface morphology of AFM pictures is assessed using the root mean square interface width and fractal dimension, and it is discovered to decrease with increasing film thickness. As the thickness of the film increases, so does the refractive index. The existence of the Raman spectrum's distinctive E2 high mode shows that the hexagonal wurtzite phase has developed in the deposited sheets. IR spectrum study reveals the integration of Al into the ZnO host lattice. The optical band gap narrows as layer thickness increases that is from 3.24eV to 3.15eV [32].

Zahra Shahedi et al. (2017) investigated an organometallic complex founded on aluminium ions for use as a luminous component in organic light-emitting diodes. XRD which is the X-ray diffraction, Ultraviolet visible and FT-IR, and Photoluminescence or PL spectroscopy were used to study the synthesized sample complex, and cyclic voltammetry was used to quantify the energy levels of the Aluminium combination. As a result, the effects of ZnO nanoparticles (NPs) on the optoelectronic properties effectiveness of organic LEDs have previously been studied. When detailed simulation results were compared and the optoelectronic performance of both the measurements with zinc oxide nanoparticles was significantly elevated than that of the specimen without the Zinc oxide nanoparticles or NPs [33].

Doo-Hee Cho et al. (2017) developed a novel methodology for synthesizing a flexible integrated organic light emitting diodes abbreviated as OLEDs substrate consisting featured metal electrode grids that did not involve etching as well as photolithographic approach and low-cost material. Since the flexible integrated substrate had a smooth surface so OLED panels could be made even without insulator structures. The electro-optical characteristics of organic LEDs devices with flexible integrated substrates were equivalent to those of glass-based organic light emitting diodes. Because the delamination processes, screen printing, electro-less copper plating, and other techniques used in our approach are well known, and the production process for flexible integrated substrates is straightforward to adapt to the current flexible Organic LED process. Our customizable organic light emitting diodes technology is expected to significantly reduce the cost of incorporating various lighting panels [34].

Khamsa Kecib et al. (2017) used the sol-gel dip-coating procedure to create aluminium doped zinc oxide films which are the AZO films on glass substrates with varied numbers of coats. X-ray diffraction or the XRD and a UV–Visible–NIR spectrophotometer are used to explore the impact of thickness on the morphological, topological and structural and electrical, optical, and wave guiding features of the generated films. All the Aluminium doped zinc oxide films, according to XRD analysis, have a hexagonal wurtzite crystal structure with such a favored growth direction along of the c-axis. With increasing thickness, the intensity of the (002) diffraction peak and crystallite size tend to increase, indicating that the crystallinity of the films improves. Microstructure properties such as grain size and surface roughness are responsive to film thickness, according to SEM and AFM images [35]. Martin Mickan et al. (2017) demonstrated that the transparent conducting oxides abbreviated as TCOs are an important class of materials with numerous uses including low emissivity coatings, photovoltaic transparent electrodes, and flat panel displays, according to Because of its inexpensive cost and accessibility of raw ingredients, al-doped ZnO (AZO) is being evaluated as a possible TCO material. Thin Al doped ZnO films are often created using physical vapour deposition processes such as magnetron sputtering. AZO films are deposited in this work utilizing high power impulse magnetron sputtering abbreviated as HiPIMS which is a process that utilizes shorter pulses with a low duty cycle to achieve high immediate current densities [36].

Gae Hun Jo et al. (2017) demonstrated graded architectures of an aluminum doped zinc oxide multilayered thinner film or coatings produced by the method which is known as the sol gel method a quartz glass substrate were presented. Various Al mol percent enriched ZnO evaluated topologies of multilayered coating or the most thinner films were being created in order to optimize the framework restriction and the diminished stress. Hence, the strain between layers was reduced by utilizing graded multilayered thin films. The X-ray diffraction or XRD technique as well as ultra-visible–vis spectrophotometer was used to explore and analyze the graded structures of multilayered Aluminium doped zinc oxide coatings or the thin films. Their study found that due to a careful balancing act graded thinner coatings formed successfully under stress reduction that crystallized well lengthwise the c-axis. Therefore, the absorption spectrum of this desired films is considered roughly 94.8 percent that is the transmittance at 400 nanometers to 800 nanometers wavelength as well as the most significant band structure should be approximately 3.27 electron volts [37].

Ram Narayan Chauhan et al. (2016) investigated as to if transparent conducting Aluminium doped zinc oxide thin coatings or the thinner films acquired by radio frequency sputtering at 2.47 Wcm^{-2} as well as the temperatures which is the low substrate temperature that is 75°C can be used as a potential substitute to indium tin oxide abbreviated as ITO considered to be used as anode for bottom emitting organic LEDs and encountered that composite materials with AZO anode have good charge balance, a high turn-on voltage, improved stability even at high current density. Inserting an Alq3/LiF/Al buffer layer right above the organic phase significantly reduces injury and damage and, as a consequence, lowers the turn-on voltage, increasing overall efficacy of transparency organic light emoting diodes or OLEDs [38].

Mariya Aleksandrova et al. (2016) investigated new material science advances and deposition techniques for flexible organic light-emitting devices. Popular plastic substrates' mechanical, optical, thermal, and chemical properties are compared. Some of the most common industrial processes for generating flexible organic LEDs include roll-to-roll printing, screen printing, and inkjet printing. The primary characteristics and issues of foil reliability, structural stability of electrical applications, including organic emissive layer fabrication and the deposition or patterning are discussed. Because of advantages like as mobility, large size, and low-cost manufacturing, flexible organic light emitting diodes will be the final choice in the display industry in the near future. There are, however, a number of challenges that must be overcome [39].

Min-Ho Park et al. (2015) studied that the flexible organic light-emitting diodes which are abbreviated as OLEDs are appropriate for next-generation solid-state lighting due to their low driving voltage, diverse color tunable, designable form, and large-area light emission. Despite being made of organic materials, the organic LEDs have evolved in terms of effectiveness, brightness, and endurance to the point where they can now be sold. Flexible organic light emitting diodes substrates should be created in order to build reliable and efficient adaptive organic LEDs for solid state lighting. To achieve this goal, advancements in the creation of superior flexible substrates, electrode materials, and encapsulation technologies that complement these flexible substrates must be achieved. Addressing the technological challenges of making high flexible substrates, electrocatalyst interoperable with all these surfaces, as well as suitable encapsulation mechanisms will help in effective and reliable flexible organic LEDs and the seeking to make flexible and the versatile solid-state illumination commercially viable [40]. Ram Narayan Chauhan et al. (2014) used radio frequency sputtered Aluminium doped zinc oxide films or thin coatings with thicknesses ranging from 110 nanometers to the 500 nanometers at low substrate temperatures ranging from 71 to 81 °C and emphasized the fact that it has a wurtzite-type hexagonal structure, similar to zinc oxide or the ZnO with such a preferential orientation of (0001). The Alminium doped Zinc oxide films or the thin coatings with a thickness of 500 nanometers have a clear transmittance of 92 percent, an electrical resistivity of $1.3x10^{-3}$ cm, and a high legitimacy figure, making them a suitable alternative to Indium tin oxide for solar panels such as organic light emitting diodes. And therefore the organic LEDs with layer succession Aluminium doped ZnO will exhibit comparable luminous flux power efficiency, supporting the use of 500 nanometers thick Aluminium doped zinc oxide coatings or the films as transparent conductors [41].

Seong-Ho Han et al. (2013) investigated the structural, electrical, and optical properties of Aluminium doped zinc oxide tin coatings or the thin films in order to support their use as anode contacts in organic light emitting diodes devices. The radio frequency magnetron sputtering was used to deposit Aluminium doped zinc oxide thin coating or the thin films in a range of encompassing gas mixtures. Charge carrier concentration has a significant impact on the electrical resistivity of Aluminium doped zinc oxide thin films. Regardless of the surrounding gases used, all Aluminium doped ZnO thin films demonstrated good transmittance. It is worth noting that the optical band gap energy of Aluminium doped zinc oxide thin coatings or the thin films has an effect on Organic LEDs device performance, particularly in terms of current density or brightness [42].

Po-Hsun Lei et al. (2013) focused on flexible organic light-emitting diodes which are abbreviated as OLEDs based on polyester sulfone or the PES and produced with dual-plasma enhanced chemical vapour deposition which is abbreviated as DPEMOCVD technology with Aluminium doped zinc oxide or the AZO as the anode. The experiment findings encompass crystallinity and the optical and the electrical properties, indicating that substrate temperature and Aluminium concentration impact the nature of Aluminium doped zinc oxide coatings or the thin films formed on the PES. The best Aluminium doped zinc oxide film collected on the PES substrate was used as the anode for flexible organic LEDs and the results show a contrast to commercial indium–tin–oxide which was abbreviated as ITO as the glass anode. As a result, the DPEMOCVD-deposited Aluminium doped ZnO coatings or the film on the PES substrate has the potential to be employed as an anode in the flexible or the bendable organic light emitting diodes [43].

Young-June Choi et al. (2013) investigated whether adding a homogenous Al-doped zinc oxide buffer layer to an Al doped ZnO anode enhances organic light emitting diodes device quality. As the Aluminium doping concentration grew, the dielectric properties of the Aluminium doped zinc oxide anode with a rather homogenous Aluminium doped ZnO buffer layer deteriorated. The work functions of the Aluminium doped zinc oxide anode with various Aluminium doping concentrations in the Al-doped ZnO buffer layer, on the other hand, climb progressively with the increase in Aluminium doping concentration from 3.1 to 5.1 at percent. The finest film properties were observed for an Aluminium doped zinc oxide anode with an Auminium doped ZnO l buffer layer that generally comprises 4.1 percent Aluminium and has a work function value of 4.64 electron volts [44].

Yuan-dong Li et al. (2012) studied whether an Al-doped ZnO (AZO) thin film, rather than an ITO electrode is a potential alternative in organic light-emitting light emitting applications because of its low cost, non-toxicity, and other promising qualities. The effect of film thickness on the structural, electrical, and optical characteristics of AZO films was successfully examined in this article, which demonstrates AZO thin films of various thicknesses produced as clear conducting films by sputtering on glass substrates. As a consequence, the results reveal that as the thickness of the film grows, the electrical conductivity improves but the optical transmittance falls, thus the optimized characteristics were reached in the 874 nm film, which had an outstanding figure of merit with an 84.4 % transmittance [45].

Zong-Liang Tseng et al. (2012) used sputtering to create 400 nanometers thick Aluminium doped Zinc oxide coatings or the films for use as transparent anodes in organic light-emitting diode devices. The Al doped ZnO device produced an outstanding luminance shield of 6450 cd/m^2 at 12.5 volts, whereas the indium tin oxide which is abbreviated as ITO device produced a good luminance shield of 9830 cd/m^2 at 10.5 volts. We observed that a hole-only device approach may be used to estimate the compatibility of Aluminium doped zinc oxide and the Indium tin oxide ITO anodes in organic light emitting diodes devices and so corroborate experimental results. As a result of the research, low-cost, non-harmful Aluminium doped ZnO coatings or the thin films may be suitable as effective anodes in high-voltage Organic LEDs devices and systems [46].

CHAPTER 3

METHODOLOGY

3.1 Deposition of AZO thin films via RF Sputtering technique

By RF (radio frequency) sputtering with a ZnO: Al_2O_3 target, Aluminium doped zinc oxide thin films were produced on glass substrates that had been cleaned, air dried, and ozone processed for around 20 minutes. The substrates were kept at a distance of 7 centimeters from the target or the target goal in a holder. Therefore, the chamber was initially evacuated to a pressure range approximately ~ $2x10^{-6}$ mbar before being filled with argon gas to a pressure of 0.15 Pascal (Pa). Deposition was carried out at radio frequency power densities of 0.31, 0.62, 1.23, 1.85, and 2.47 Wcm^{-2}. A digital monitor was used to manage the layer thickness which is approximately about 400 nm. The substrate was originally kept at 25°C, but it reached a maximum or extreme temperature of 75° Celsius through the deposition of 400 nanometers thick layers. To measure the temperature, a thermocouple is put inside the working chamber. A digital temperature indicator shows the temperature of the substrate. For phase identification, an X-ray diffractometer was used. he optical transmittance spectra of Aluminium doped zinc oxide thin coatings or thin films sputtered at various radio frequency power densities were examined. As transparent conducting anodes for the OLEDs, Aluminium doped ZnO sheets with Radio frequency power densities of 0.62 and 2.47 Wcm^{-2} were employed [47].

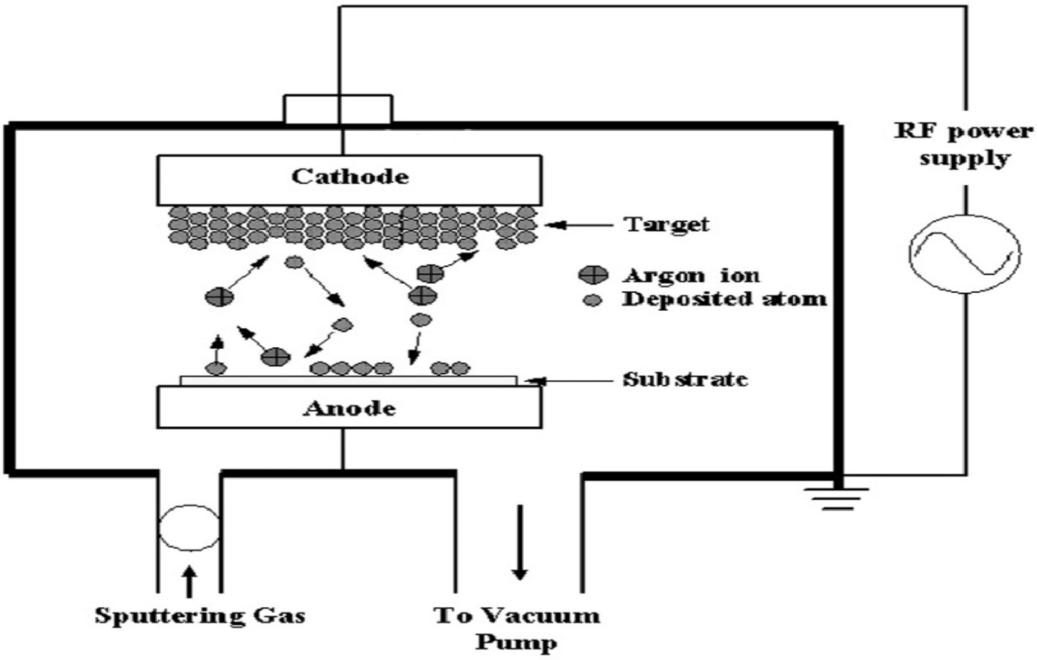


Figure 3.1 RF Sputtering System Schematic Diagram [48].

3.2 Synthesis of graded Al-doped ZnO multilayer thin film via sol–gel method

A sol–gel method which is one of the most appropriate method was used to create graded Al doped zinc oxide multilayer which is regarded as the film that has structures onto the glass substrates. Starting ingredients included zinc acetate dihydrate ($Zn(CH_3COO)_2H_2O$) and aluminium chloride hexahydrate ($AlCl_36H_2O$). As a solvent and a stabilizer, 2-Methylethanol and monoethanolamine abbreviated as MEA were utilized. To minimize strain, different Al doping concentrations were used in the structure which is being the multilayer to change the characteristics of lattice. MEA to zinc acetate dihydrate molar ratio must have been stayed consistent at 1.0, however respectively the zinc acetate dihydrate attentiveness was kept at 0.7 mol/l. As dopants, 0.17, 0.33, 0.5, 0.66, 0.83, and also the 1 mol percent % Aluminum were additional to zinc oxide in appropriate proportions. Therefore, resulting solution was agitated for 2 hours at 60 degrees Celsius. The spin coating process was used to drop the solution onto glass substrates. Following the sol gel spin coating deposition s therefore the films are dried in the hot air at 300°C for 10 minutes on a hot plate help evaporate the solvents or fluids and organic compounds or organic matter. X-ray diffraction abbreviated as XRD was used to investigate the crystallinity of an assessed Al doped Zinc Oxide coated multilayered structure or multilayered configuration [49].

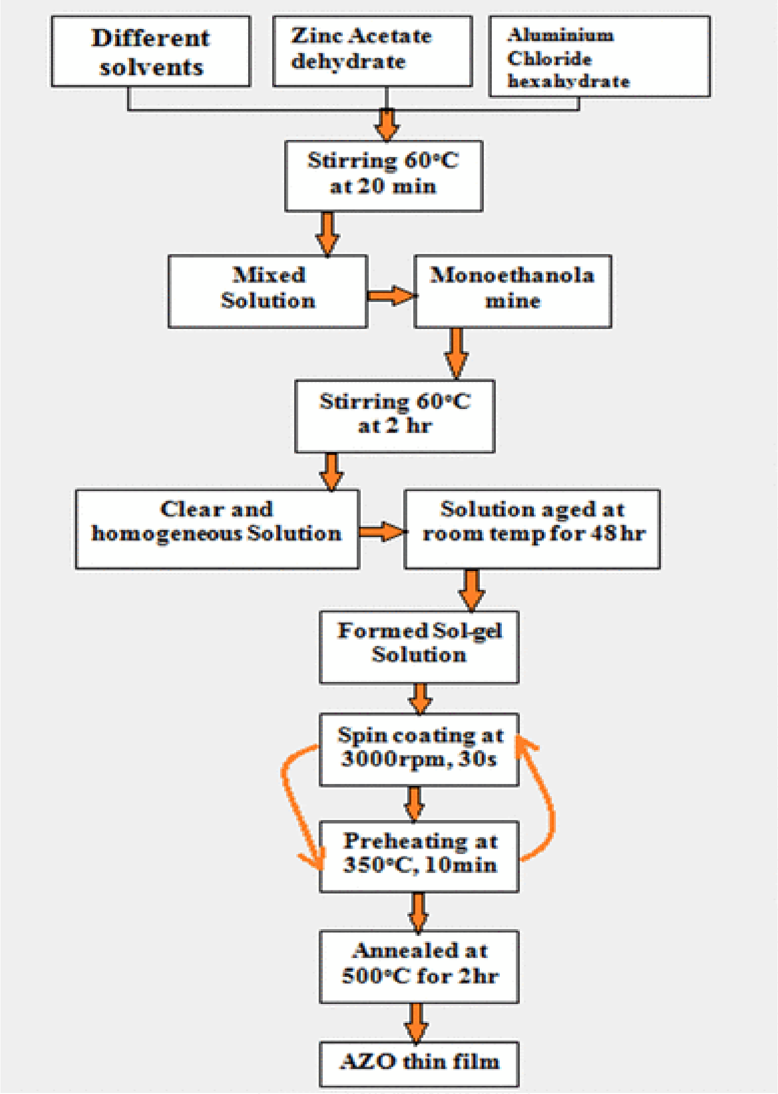


Figure 3.2 The sol–gel spin coating technique for the deposited AZO thin films is depicted in a flow chart [50].

3.3 Techniques for the characterization

3.3.1 X-ray diffraction (XRD) for structural analysis

X-ray diffraction analysis abbreviated as XRD is a materials science method used to determine the crystallographic structure of a material. The technique of X-ray diffraction includes irradiating a material with incoming X-rays and then measuring the intensities and scattering angles of the X-rays that escape the substance. One of the most popular uses of XRD analysis is the identification of materials based on their diffraction pattern. In addition to phase identification, XRD offers information on how the real structure differs from the ideal one owing to internal stresses and defects. XRD has many advantages and applications, including the fact that it is a non-destructive technique for identifying crystalline phases and orientation, as well as determining structural properties such as lattice parameters, grain size, epitaxy, strain, phase composition, preferred orientation, and phase composition). The atomic arrangement and thickness of thin films and multilayers are determined using XRD [51].

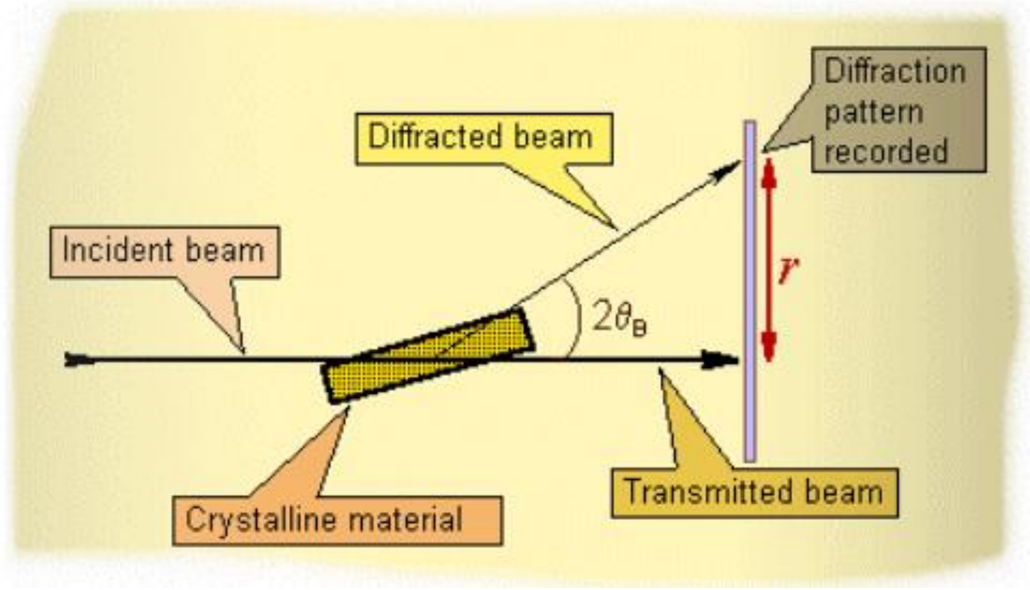


Figure 3.3 Detailed diagram of XRD [51].

3.3.2 Ultraviolet-visible (UV-Vis) spectrophotometry for optical analysis

UV-visible or UV-Vis spectrophotometry is a method used to measure optical absorption in the ultraviolet and visible wavelength ranges of the electromagnetic spectrum. When incident light strikes a medium, it can be absorbed, reflected, or transmitted. The absorption of Ultraviolet-visible light causes atomic excitation, which refers to the change of molecules from such a low or minimal ground state to an excited state [52].

CHAPTER 4
RESULTS

4.1 Structural Analysis by XRD via RF sputtering method

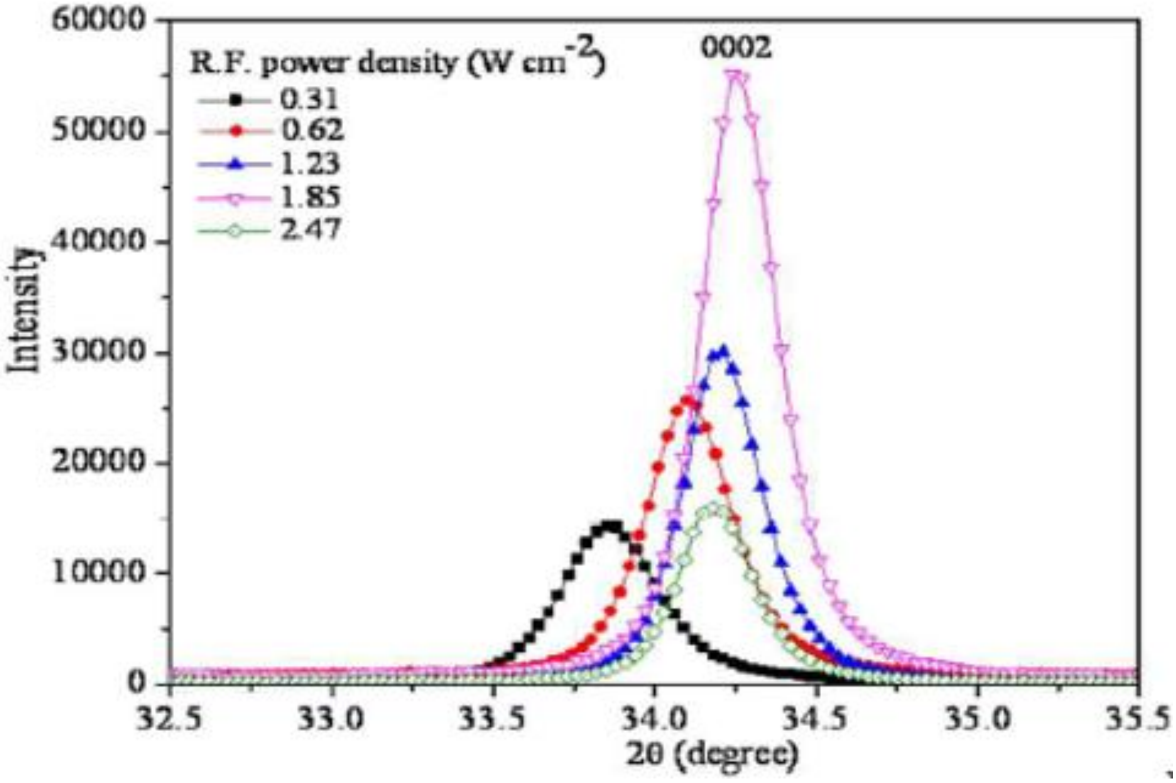


Figure 4.1 X-ray diffraction peak 0002 of AZO thin films deposited by sputtering at R.F. power densities of 0.31, 0.62, 1.23, 1.85, and 2.47 Wcm^{-2}, respectively [47].

This figure is a graph of Intensity and Braggs angle (2θ). This graph was created using the X-ray diffraction or XRD technique, which discovered the structure of AZO thin films with the preferred orientation when deposited using RF sputtering at various power densities. The radio frequency power density will be 0.31, 0.62, 1.23, 1.85, and 2.47 Wcm^{-2}, respectively. Therefore, the X-ray diffraction analysis or the XRD pattern of the Aluminium doped zinc oxide thin coatings or the thin films deposited at the 0.31 Wcm^{-2} corresponds to a structure which is a wurtzite-type hexagonal with [0002] preferred orientation, which is the c-axis perpendicular to the substrate, as shown in Figure (4.1). For the fabrication of the OLEDs Aluminium doped zinc oxide thin coatings or films with radio frequency power densities of 0.62 and 2.47 Wcm^{-2} were used as transparent conducting anodes as in bottom emission type [47].

4.2 Optical analysis via RF sputtering method

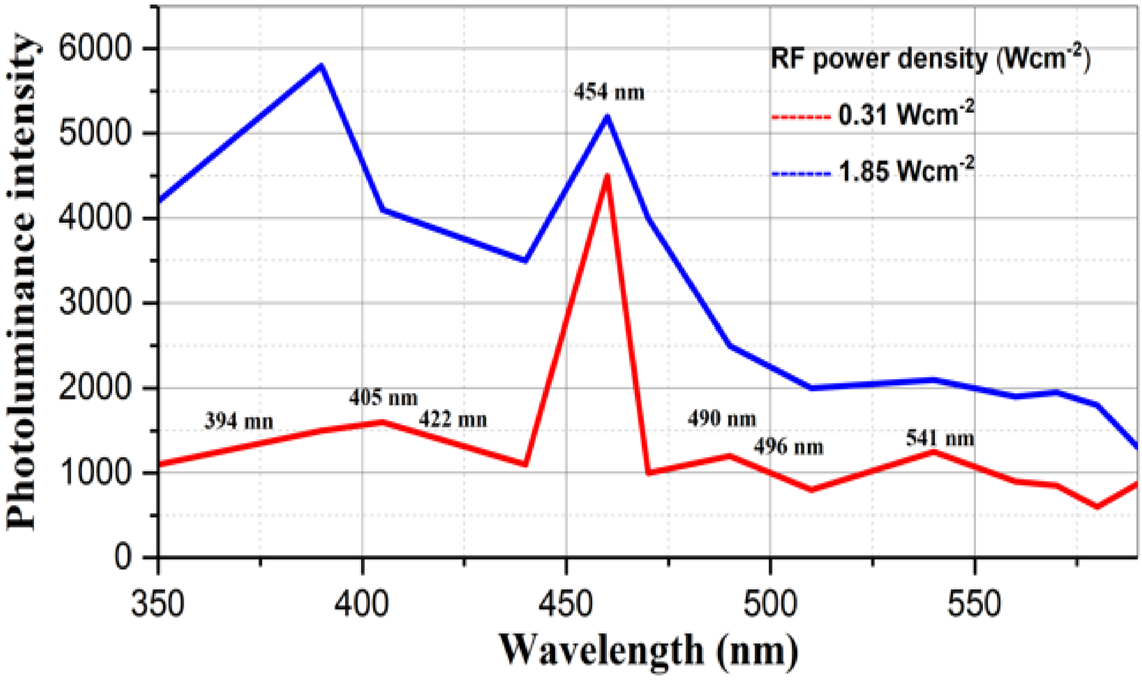


Figure 4.2 Photoluminescence or the PL spectra of R.F. sputtered AZO thin films at 0.31 and 1.85 Wcm^{-2} RF power density [47].

This figure is a graph of photo-luminance intensity as a function of wavelength in nanometer and the RF power density in this case will be considered as 0.31 Wcm^{-2} and 1.85 Wcm^{-2}. The Edinburgh Steady State Fluorimeter FS920 was used to record the photoluminescence (PL) to reveal the nature of the faults present. Following optical excitation, photoluminescence (PL) is the spontaneous emission of light from a substance. The emissions were measured at several wavelengths, including 394 nm, 405 nm, 422 nm, 454 nm, 490 nm, 496 nm, and 541 nm [47].

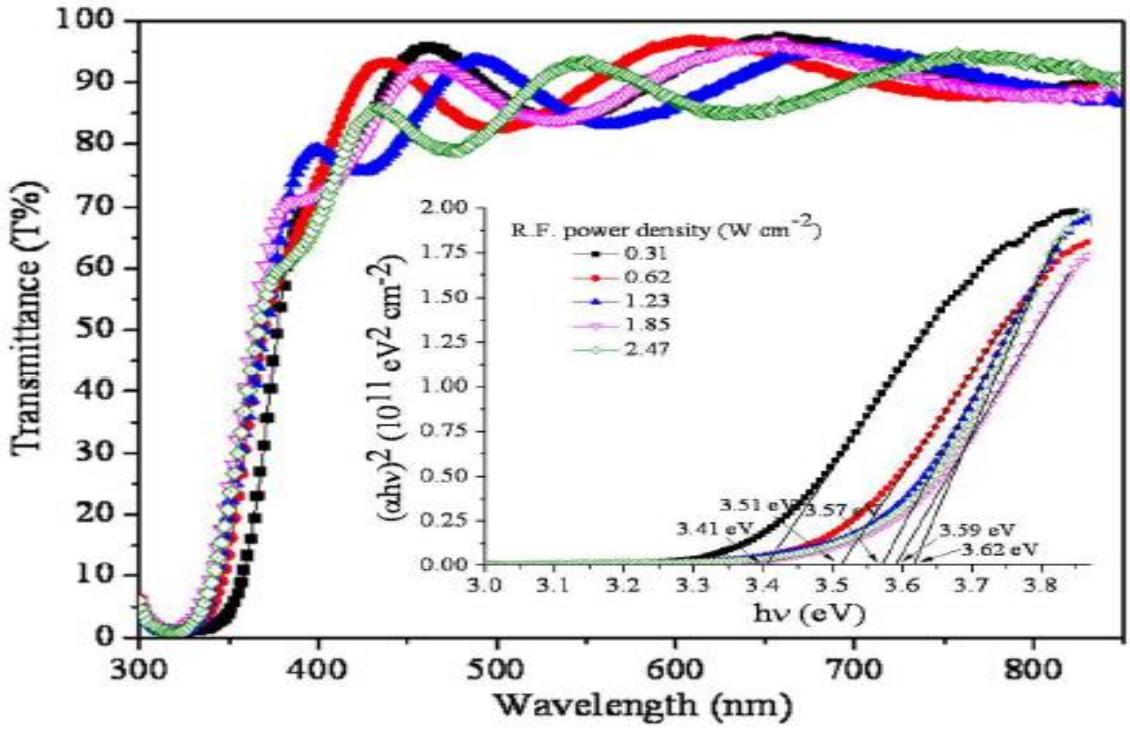


Figure 4.3 Spectra of optical transmittance of AZO thin films sputtered at various R.F. power densities [47].

This figure is a plot of transmittance vs wavelength. The transmittance spectra of Aluminium doped zinc oxide thin films deposited by sputtering at various radio frequency power densities are shown in Figure 4.3. The effect of film thickness on the optical properties of AZO thin films deposited using the significant RF sputtering method will be reported using this graphical analysis. In the visible region, these have average transmittances of around 90% and an absorption edge that shifts to a lower wavelength. The film's optical energy band gap (Eg) is calculated from the intercept of the linear fit of $(hv)^2$ vs h or Tauc plot with the energy axis as shown in the inset of Figure 4.3 and also where absorption coefficient α = (- lnT/t where T is transmittance, t is film thickness) [47].

4.3 Structural analysis by XRD via sol-gel method

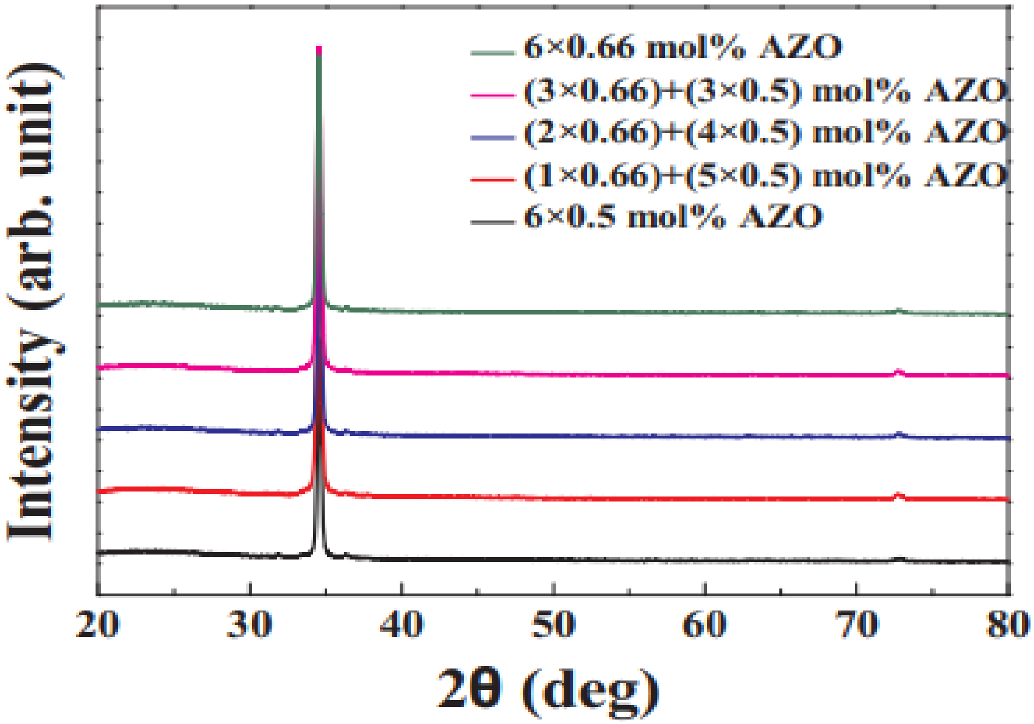


Figure 4.4 Graded AZO multilayer thin film X-ray diffraction patterns on glass substrates [49].

This graph is plotted between intensity and Braggs angle (2θ). With respect to different film thicknesses, the optical properties and crystallinity of Aluminium doped zinc oxide thin coatings or thin films will be investigated. This diagram depicts the hexagonal structure of wurtzite, which peaks at 0002 with preferred orientations. We also learned about the serious stress-strain issues associated with various film thicknesses using this graph. As shown in figure (4.4) the structural properties or the structural configuration of the rated Al doped ZnO thin film multilayered composition were examined through X-ray diffraction or XRD [49].

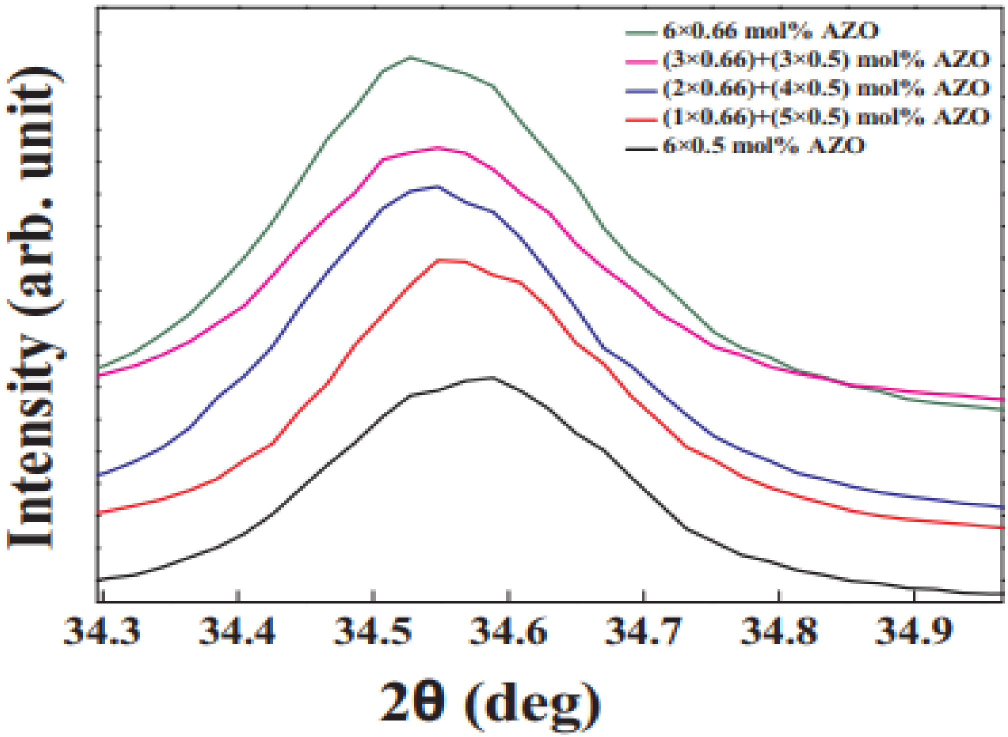


Figure 4.5 Magnified XRD patterns of Al doped zinc oxide multilayered structure of thin film graded 6 × 0.5, (1 × 0.66) + (5 × 0.5), (2 × 0.66) + (4 × 0.5), (3 × 0.66) + (3 × 0.5), and 6 × 0.66 [49].

This figure shows the graph between Intensity and Braggs angle. This graph illustrates the result of the synthesis of a multilayered film which is approximately thin and the thin film was of Al doped zinc oxide structure using the method which is the sol-gel method. The mol percent of Al doped ZnO layers will be focused in the resulting peak position. The (002) peak position decreases to a lower angle when the amount of 0.66 mol percent the Aluminium doped ZnO deposits increases as shown in figure 4.5. This indicates that the preferred c-axis lattice parameter has been increased. As a result, in order to compensate aimed at the higher lattice parameter which is the c parameters, the stress in the in-plane direction can be reduced [49].

4.4 Optical analysis via sol-gel method

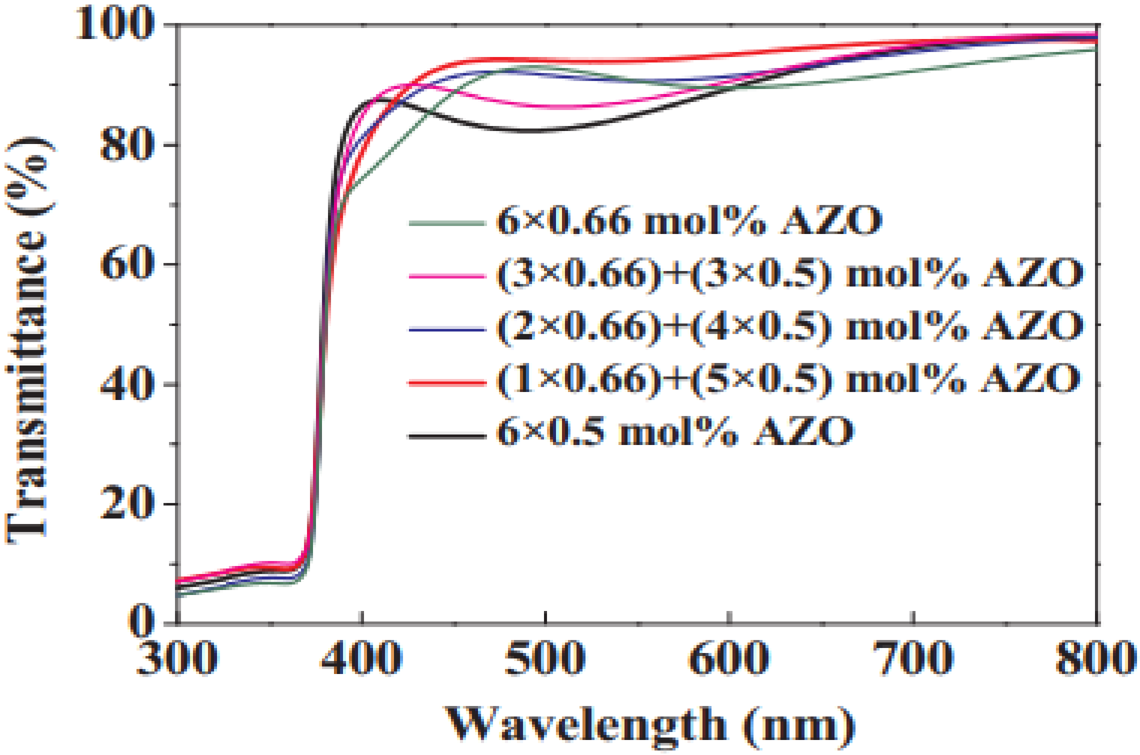


Figure 4.6 At 300–800 nm wavelength, the grading AZO multilayered coating structure's transparency is assessed [49].

This figure shows the result of transmittance when the graph is plotted between transmittance (%) and wavelength which is measured in nanometers. Different mol% concentration were also recorded that depends at their concentration of Aluminium doped zinc oxide layers. Ultraviolet visible spectrophotometry has been used to quantify optical transparency. Figure 4.6 shows the optical transmittance findings for the graded AZO multilayer thin film recorded in the 300nm to the range of 800 nm range [49].

Table 4.1 contains detailed transmittance statistics [49].

Table 4.1 Data on average transparency using graded Aluminium doped ZnO multilayered thin coatings or the thin films [49].

Graded AZO multilayer thin film type	6x0.5	(1x0.66)+(5x0.5)	(2x0.66)+(4x0.5)	(3x0.66)+(3x0.5)	6x0.66
Average transmittance	90.12	94.79	92.75	91.92	90.61

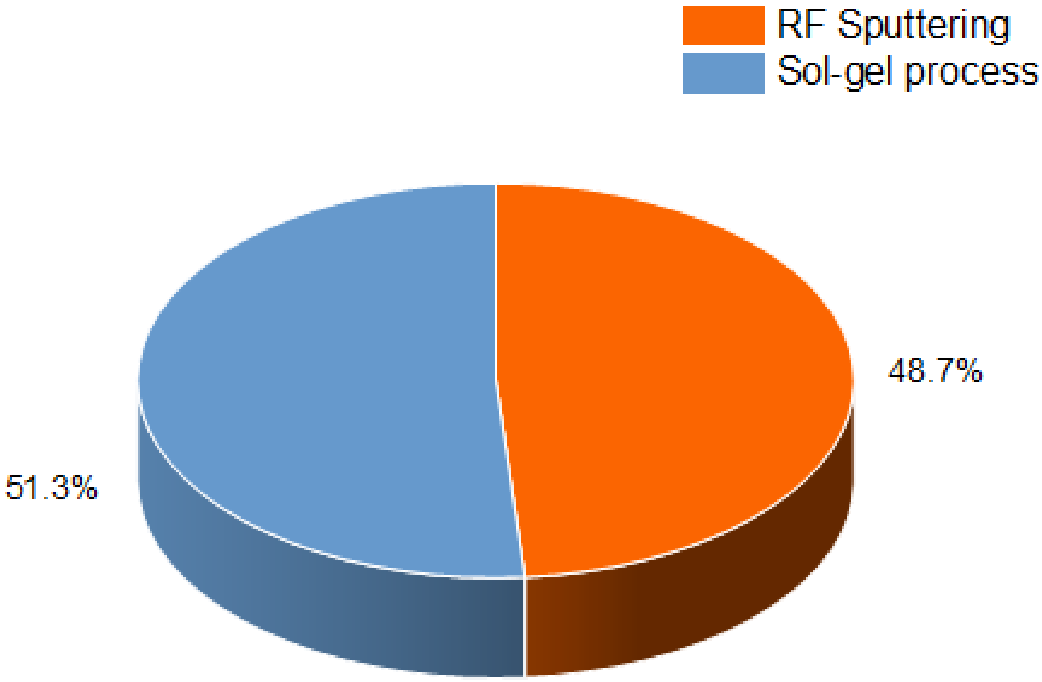


Figure 4.7 Comparison of Optical Transmittance obtained by RF sputtering and Sol-gel process [47,49].

This figure shows the optical transmittance of AZO thin films by two different and most significant methods which are RF sputtering method and the other method was Sol-gel method. Optical transmittance was one of the most important property being reported in different device applications such as OLEDs [47,49].

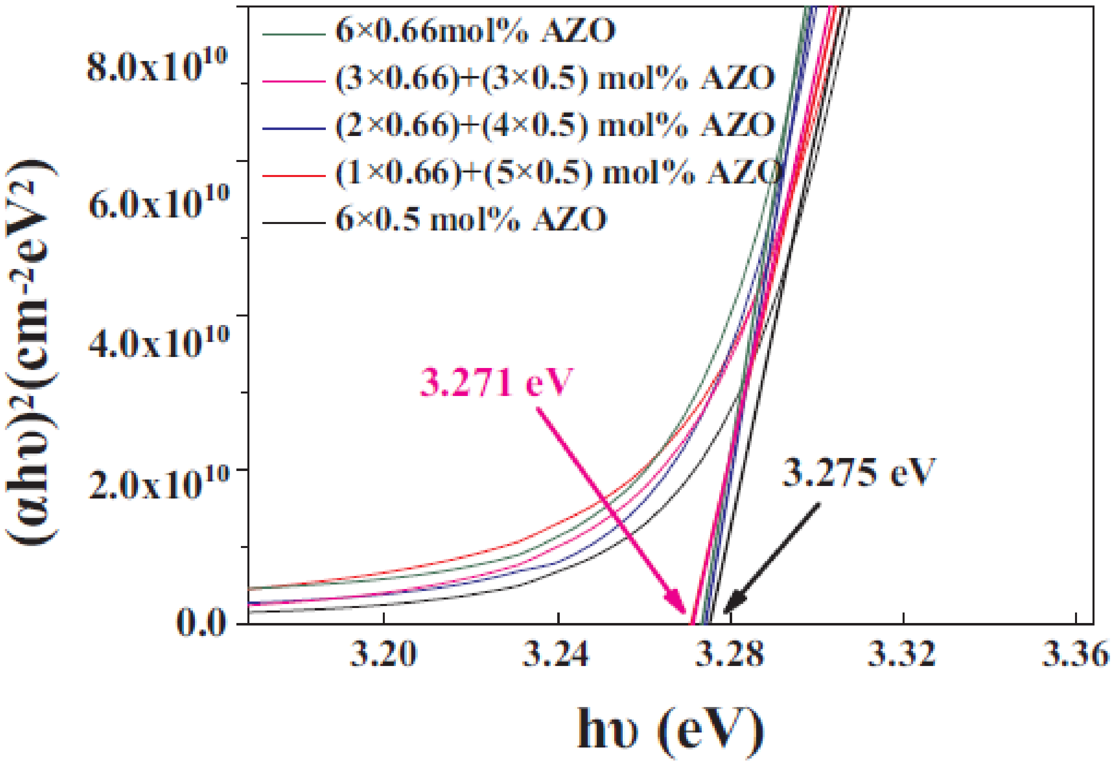


Figure 4.8 The linear fit of transmittance to the energy band-gap [49].

Using the equation $\alpha = (1/d) \ln (1/T)$ where d and T are the thickness and transmittance of the films, respectively, the absorption coefficient can be calculated from the transmittance data. The optical band gap energy of graded Al doped ZnO multilayered thinner films was calculated using the $(\alpha h\nu)^2$ contrasted with $(h\nu)$ shown in figure (4.8) [49].

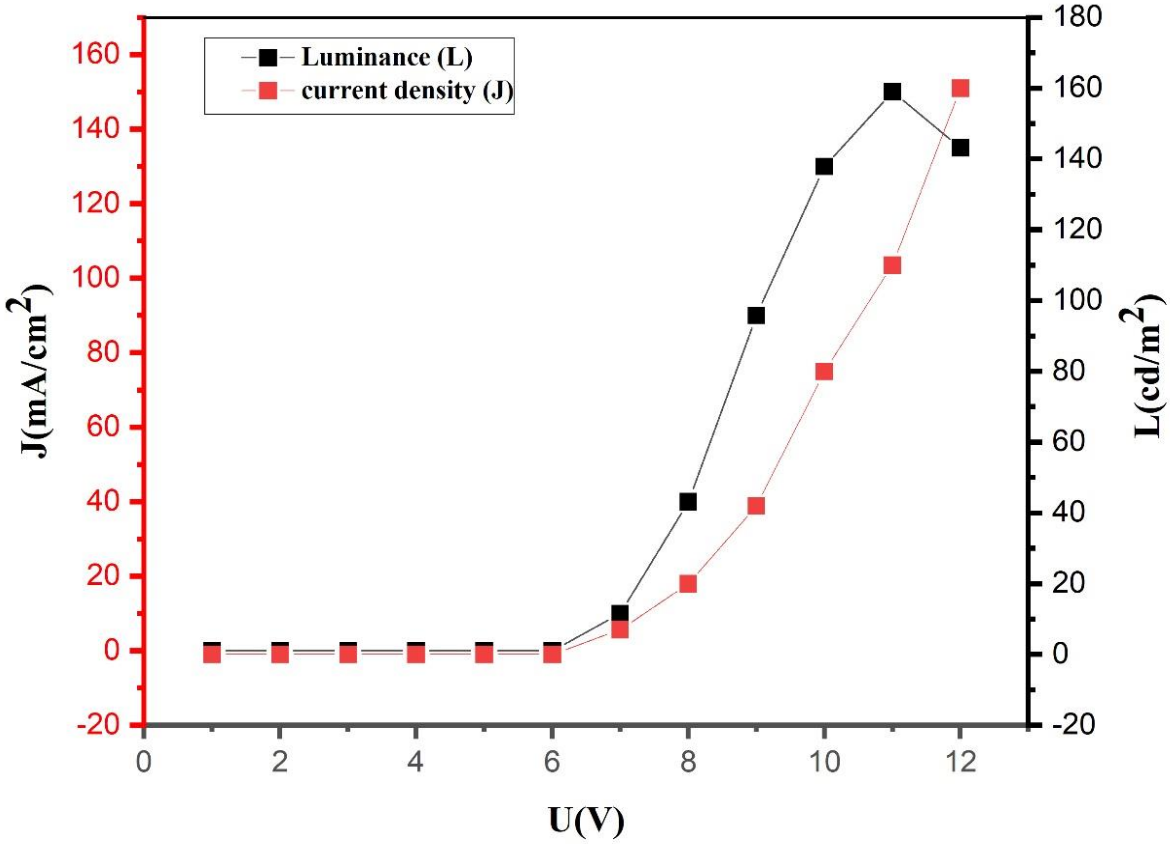


Figure 4.9 The J-V versus L-V curves have been recorded and its measurements was shown [53].

Figure 4.8 depicts the charts of current density which is abbreviated as J and the brightness or L as a consequence of driving strength or U. The experimental study revealed a switching voltage of around 6 volts and a rated current density or current of more than 150 milliampere/cm^2 at the driving voltage of 12 volts [53].

CHAPTER 5

DISCUSSION

The X-ray diffraction pattern of Al doped zinc oxide thinner films generated at 0.31 Wcm^{-2} counterparts to just a wurtzite-type hexagonal construction with [0002] preferential orientation, the c-axis perpendicular to the base, is shown in Figure (4.1). The 0002 diffraction peak grows stronger as the radio frequency power density used for film preparation rises, changes to a higher Bragg angle which is 2θ, and reaches 2θ which is equal to 34.241 degrees with maximal strength at the 1.85 Wcm^{-2}. In films produced at a power density of 2.47 Wcm^{-2} 0002 is the diffraction peak which emerges at a lower angle which is $2\theta = 34.181°$ and albeit with a reduced intensity. The crystallinity of the films improved only when the RF power density employed for deposition was increased from 0.31 Wcm^{-2} to 1.85 Wcm^{-2}. In addition, as the crystallinity of AZO films improves, the c- parameter lowers. Film degradation occurs at greater RF power densities, and the lattice parameter increases significantly. For generating AZO films with wurtzite-type hexagonal structure, [0002] preferred orientation, the optimum radio frequency power density for the sputtering appears to be considered as 1.85 Wcm^{-2}. At RF the power density of the 2.47 Wcm^{-2} the peak 0002 appears to be pushed towards lower Bragg's angle which is $2\theta = 34.18°$. We were unable to deposit films larger than 2.47 Wcm^{-2} due to the limitations of our sputtering technology, preventing us from seeing and analyzing the trend. To determine the precise inclination and reason of peak shifting at greater radio frequency power densities, additional data and the research exceeding 2.47 Wcm^{-2} will be required in the nearer future [47].

As shown in figure (4.2) the photoluminescence which is abbreviated as PL spectra of aluminium doped zinc oxide the thin films generated with a 309 nm excitation wavelength are presented. It is worth noting that the aluminium doped zinc oxide film produced by sputtering at 0.31 Wcm^{-2} emits at 395 nanometers at the band edge and the 405 nanometers and 422 nanometers as violet and the 454 nanometers regarded as as blue and 490 and 541 nanometer regarded respectively as green. Whereas the violet emission at 405 nm with 3.06 electron-volts of energy is affiliated with the transformation from the conduction band to the energy level of zinc vacancy, the near band edge emission at 394 nm with 3.15 electron-volts is ended up causing by free exciton recombination and therefore is dependent on the film crystallinity, which really is VZn. Therefore, the obtained Aluminium doped zinc oxide films display better photoluminescence conforming to blue and green emissions at the 2.73 and 2.53/2.29 electron-volts, respectively, when the radio frequency power density is increased to 1.85 Wcm^{-2} [47].

Figure (4.3) shows AZO thin film transmittance spectra placed by the sputtering at various radio frequency power densities. In the visible area, these have typical transmittances of around 90%. In addition, as the radio frequency power density increases as the result the absorption edge changes to the lower wavelength or greater energy. An increase in carrier concentration might be the reason of this. As demonstrated in the inset of figure (4.3), the resultant values of Eg rise from 3.41 electron volts to 3.62 electron volts with an increase in carrier concentration from $6x10^{19}$ to $6.26x10^{20}$ cm^{-3}. Aluminum doped zinc oxide thin films deposited by RF sputtering at power densities of 0.31, 0.62, 1.23, 1.85, and 2.47 Wcm^{-2} have the work functions of 3.90 and 3.92, and also 4.40, 4.42, and 4.44 eV, respectively. After exposing the films to ozone for 20 minutes, the values improve by 0.2–0.3 eV. According to the above findings, AZO films sputtered at 2.47 Wcm^{-2} can be used as anodes in OLEDs because to their high work function whilst those sputtered at 0.31 Wcm^{-2} can be used as cathodes due to their lower work function [47].

The figure (4.4) showed successfully the X-ray diffraction peaks of rated Aluminium doped zinc oxide multilayer nanostructures thin films on glass substrates. As seen in the image the graded Al-doped ZnO multilayered thinner films manifested effectively upon glass substrates. There were no discernible pyrochlore peaks in the (002) peaks. Results suggests that now the graded Al-doped ZnO multilayered nanosheets done and the results on the substrates with little stress-strain difficulties. More stringent experiments were performed on the graded aluminium doped zinc oxides multilayered thin film, particularly when combined with 0.5 mol percent Al doped ZnO and 0.66 mol percent Al doped ZnO layers and in order to clearly identify the stress and strain consequences of graded al-doped ZnO multilayered thin films on glass substrates [49].

Figure (4.5) demonstrates how reduced in-plane stress enhances the electrical and optical characteristics of a graded Aluminium doped zinc oxide multilayer thin film for electronic applications. Reduced defects for example can improve conductivity current, thermal on-resistance, or photonic transmission. Furthermore, reduced stress and minimal defects have the same meaning, and fewer flaws uniformed the inner structure, lowering dispersion in Al-doped ZnO multilayered the thinner films. Device performance as well as the system performance can be increased massively of the reduced stress. As just a result, minimizing thin film stress greatly enhances and matching the lattice characteristic amongst sheets. The stress of 1 layer of 0.66 mol percent % Al doped zinc oxide in the center position of the multilayered thinner film has the minimum stress in each scenario due to the well-matched lattice attributes [49].

Fig. 4.6 and Table 4.1 show that the optical transmittance of all graded Aluminium doped zinc oxide multilayered thin coatings or the thin films was higher than 90%. When compared to other structures, the graded Aluminium doped ZnO thin films with one intermediate layer containing 0.66 mol percent Al-doped zinc oxide multilayer thin layer had the maximum optical transmittance value of 94.17 percent. Therefore, all transmittances of graded AZO multilayer thin films have abrupt absorption edges in the wavelength region of 370 to 400 nanometers, which has been employed in a number of device applications including organic light emitting diodes OLEDs [49].

Figure (4.7) compares the transmittance of thin films deposited by radio frequency sputtering and the sol-gel processes. The transmittance obtained by the RF sputtering approach is roughly 90% in the visible area, whereas the transmittance obtained by the sol-gel process is 94.79 percent in the 400-800 nm wavelength range. As a result, when it comes to attaining high transmittance, the sol-gel technique will be preferred for most device applications such as OLEDs.

Figure (4.8) shows the band gap energy which is the optical band gap energy and it is ranged between 3.271 electron volts and the 3.275 electron volts. Therefore, this

broad optical bandgap representative of Aluminium doped zinc oxide multilayered which is a thin films layered has various advantages in terms of the device and the many important system application, but it has the disadvantage of device such as the OLEDs functioning due to the high threshold voltage. However, if the TCO (Transparent and Conductive Oxide) thin film with a broad optical bandgap is applied to a device and as a result the heating concerns could be decreased due to the reason of the low intrinsic electron level caused by the material's wide optical bandgap. As a result, the wide bandgap thin film's strong thermal resistance quality implies capabilities for many device applications such as the widely used thin film gas sensors as well as the organic light emitting diodes which are the OLEDs [49].
Figure (4.9) indicates that the device performance degrades when the voltage above 11 volts with the peak brightness of roughly 160 cd/m^2 measured directly at driving voltage which is U = 11 V and current density which is J = 150 mA/cm^2. This graph depicts the operation of a realistic device such as OLEDs, in which we can see very brilliant and homogenous emission inside the device region [53].

CONCLUSION

The sol-gel technique and radio frequency (RF) approach were utilized in this work to synthesize Al doped ZnO for device applications such as OLEDs. Transparent conducting AZO thin films produced by the radio frequency sputtering with a power density and the power density will be respectively of 2.47 W cm^{-2}, therefore 75°Celsius is considered as the low substrate temperature that can be used as anodes for bottom emitting OLEDs instead of Indium tin oxide ITO. The AZO anode-fabricated devices feature good charge balancing and better durability as well as stability even at the current density which is high and perhaps a significant turn or switch voltage. Sputtered at low power densities, such as 0.31 Wcm^{-2}, the Aluminium doped zinc oxide films have a relatively low function, act as an efficient charge injector, yet are thus acceptable for the cathode of transparent organic light emitting diode or OLEDs. An increase in radio frequency power density during aluminium doped zinc oxide thin film sputtering produces visible damage to the organic layer, raising the threshold as well as sensitivity and switch-on voltage of a transparency organic light emitting diodes or OLEDs. And therefore the insertion of such an Alq3/LiF/Al buffer layer right above the organic layer reduces the significant damage and also lowers switch voltage therefore improves the organic light emitting diode (OLEDs) performance [47].

On a glass substrate, grading patterns of Aluminium doped zinc oxide multilayer ZnO films which are the thin films were produced using a sol-gel technique. The sol-gel technique has shown to the most suited method for the production of Aluminium doped zinc oxide multilayered thinner films for device applications such as OLEDs. The stress reduced architecture was done in order to improve the lattice constants and also the parameters in the multilayered zinc oxide or ZnO films which are the most thinner films which showed the lower strain readings than the multilayered construction or framework. Reduced stress and strain have a significant impact on sheet resistance and optical transmittance quality as a result of the lessened lattice incompatibilities induced by the thin coating growth process or development process. Because of the low strain and the stress, the thin coating had minimal flaws, which may enhance optical and electronic properties by eliminating stranded contact electrons as well as optical dispersion scattering respectively. With an optical energy band gap of 3.271 electron volts to 3.275 electron volts, this sol-gel method achieved a maximum transmittance which is a high transmittance of 94.8 percent throughout the 400 nanometers to 800 nanometers wavelength range. Apparently graded or the scaled Aluminum-doped oxide multilayered thin films precipitated adequately on the glass substrates and also the significant (002) levels or peaks that were clearly observed in the absence of pyrochlore levels or peaks and therefore indicates that the grade or scaled aluminium doped zinc oxide multilayer nanosheets or thinner films developed successfully on the platforms with little stress strain limitations. This optimization of structure as well as het proposed approach of the Aluminium doped zinc oxide thin films or thin film coatings successfully revealed a link between electrical and optical properties and reduced strain and stress. The sol-gel method has important implications for creating trustworthy aluminium doped zinc oxide multilayered nanostructures or the thin film coatings with minimal strain-stress for device applications such as OLEDs [48].

LIMITATIONS

- Access to the articles and the journals relevant to this research topic available online was limited.
- Due to the constricted lab resources access to sample characterization techniques was limited.

RECOMMENDATIONS

- Due to hazardous nature of the source gases used for deposition, special safety measures are essential in the fabrication of thin film photovoltaics.
- There should be no air contamination in sample preparation.
- When statistical analysis of the data is required, a professionally prepared sampling process is suggested.
- Data analyzation of the characterized data must be noted or carried out with critical precision.
- The rise in R. F. power density during AZO film sputtering should be managed; otherwise, it would cause observable damage to the organic layer, boosting the threshold voltage and turn-on voltage of a transparent organic light emitting diode or OLED.

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