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Fabrication of Transparent Thin Film for Application of Thin Film Transistor (TFT) and Microelectronics

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Abstract

A thin-film transistor (TFT) is a special type of metal-oxide-semiconductor field-effect transistor (MOSFET) made by coating an insulating substrate with layers of an active semiconductor layer, metallic contacts, and the dielectric layer. FET transistors consist of three main components: source, gate, and drain. The main objective of the work is to fabricate the channel component by growing the ZnO nanostructure on the glass substrate using spin coating and spray pyrolysis methods. Thin films of zinc oxide (ZnO) were deposited on glass substrates by spin coating techniques from a precursor solution containing zinc acetate, ethanol and hydroxide of ammonia. After deposition, the films were centrifuged and evaporated. The application of spray pyrolysis has been used to deposit a wide variety of thin films, which are used in a variety of devices, such as solar cells, sensors and solid oxide fuel cells. It has been observed that the properties of the deposited thin films often depend on the preparation conditions; concentration levels of the precursor solution, coating time, electrical and optical properties of the glass substrate, etc. The average resistance of the sheet of samples F1, F5, F52, and F57 was 8.7 Ω, 9.14 Ω, 8.9 Ω and 9.42 Ω and of the samples, F2, F29, F39, and F53 were 9.5 Ω, 9.3 Ω, 9.9 Ω, 10.0 Ω respectively, at a growth temperature of 340 ^{0}C. The thin films of ZnO were found to be highly transparent between the visible and near-infrared regions of the electromagnetic spectrum and the transmission of each sample decreases with three layers of ZnO seed layer. The decrease in the transmission of the samples confirms the coating of the ZnO seed layer on it. This work has demonstrated that transparent thin films can be fabricated using local techniques developed from locally available materials using less harmful chemical reagents such as zinc acetate. Such fabricated films are optically absorptive and inherently transmissive, further suggesting that they can be used as channel material in thin film transistors.

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1. Introduction

Thin film technology is most prevalent in the commercial and laboratory sectors and is in high demand due to its versatility in a variety of applications. Thin films can be grown for Solar cells (Chopra et al., 2004), thin film batteries (Bates et al., 1993), coating devices (Inokuti et al., 2007), thin film transistors (Hoffman et al., 2003), etc. Thin film transistors can be processed commercially and can design available color displays in many products, such as TVs, tablets, digital photo frames and mobile phones. Additionally, ZnO is a promising material due to its unique characteristics, which include non-toxicity, simplicity of composition, recyclability, and abundance in the earth (Ko Park et al., 2008). The physical or chemical deposition process is used to deposit a thin film on a substrate or pre-deposited layer. Physical vapor deposition, laser ablation, molecular beam epitaxy and sputtering are some of the physical methods. Chemical methods include vapor deposition and solution methods. Chemical vapor deposition and atomic layer epitaxy are gas-phase methods, while spray pyrolysis, sol-gel method, spin coating method, and immersion method use a precursor solution. The thin film phenomenon has been studied for the past three centuries. However, in recent decades it has been used in a wide range of applications in many fields. In addition, it seems that many researchers in the field of thin film deposition are interested and have obtained consistent results by performing changes in parameters such as changes in dopant, pre-cursor, temperature, molar concentration, etc. Many experiments have been carried out around the world in this field. In most cases, donor-type ZnO doping to zinc oxide appears relatively simple by doping it with a Group III impurity (zinc atomic substitution) or a Group VII impurity (oxygen atomic substitution), such as B, Al, GaIn and Zr). F, Cl, and I. Doping increases the carrier concentration and provides conduction electrons to reduce resistance. However, excessive doping can cause ionized impurity scattering centers in the ZnO lattice. Therefore, electron mobility decreases. As a result, it is necessary to control the amount of doping. Doped ZnO usually exhibits n-type conductivity due to Zn or oxygen vacancies (Joseph et al., 1999).

1.1 Chemical vapor deposition

A typical Chemical vapor deposition process involves exposing substrates to volatile gaseous precursors, which react or decompose on the substrate surface before being deposited as a film. The reaction and decomposition of these precursors are induced using a variety of techniques. Thermal and plasma-assisted processes are two typical types. The most popular technique for creating CNTs is thermal methods using catalytic CVD (Sharma and Lakkad 2009), and doping of graphene with N-doped graphene (Wang et al., 2010). Hot filament (or hotwire) and thermal CVD are two common thermal dissociation methods for producing carbon films. Production of different structured films has increased as a result of popular CVD variations that use plasma-enhanced CVD (PECVD) techniques. Even at low substrate temperatures, PECVD encourages strong film adhesion. PECVD methods are frequently used to create carbon films with nanostructures. Additionally, they enable exact control over the positioning, length, and diameter of these nanofibers or nanofilaments (Kumar et al., 2001). It is possible to create these structures with excellent vertical alignment that is directed by the electric field established in the plasma. Moreover, individual freestanding nanostructures could be created by carefully adjusting the deposition parameters.

1.2 Pulsed-laser deposition (PLD)

A well-known method for the synthesis of carbon-based amorphous materials, such as diamond-like carbon and nitrogenated carbon films, is pulsed-laser deposition (PLD) (Matenoglou, 2007). PLD is a method that uses a vacuum system to focus a pulsed laser beam onto a target material. Because of the intense energy at the focal point, the target material ablates off, flies across the vacuum chamber, and finally sticks to a nearby substrate to form a thin film. Due to the presence of high-energy evaporates and quick response times, PLD can form hydrogen-free films from congruent evaporation with good crystalline. This enables the formation of high-quality DLC that contains a significant amount of sp3 hybridized carbon atoms. Simply altering the substrate’s orientation about the target surface could increase structural uniformity by reducing the co-deposition of micron- and sub-micron-sized particles. Additionally, this technique allows for a fair control of nanoparticle size, allowing for the production of single-walled CNTs of high quality and purity with the proper monitoring of their deposition parameters. several traditional PLD systems consisting of a biased or unbiased substrate configuration, a laser source, and a carbon (graphite) target. The dynamics and behavior of the radiation plume created by the laser ablation have a significant impact on the film-deposition process. The kinetic energies of carbon ions in the plume and the substrate temperatures are the primary controlling factors for the formation of DLC with high sp3 content. The energy (wavelength) of the laser radiation source regulates the kinetic energies of the species ions (Paul et al., 2008). Nd: YAG lasers and excimer lasers, which produce thin films with uniform surface morphologies, are common sources.

1.3 Sputtering Method

According to reports, the most popular industrial method for depositing diamond-like carbon coatings films is sputtering. A material used as a solid sputtering target is typically placed on a dc-powered electrode when using the sputtering technique. Due to the bias that has been applied to this electrode, the target surface would be bombarded by energetic particles produced from an inert gas plasma, typically Ar. Atoms from the target may be ejected or spewed out when the bombardment energy is high enough. Thin films might be deposited when these atoms get to a substrate. Sputtering has many benefits, including control over film homogeneity and a straightforward process. In particular, for the fabrication of diamond-like carbon coatings, this method could also be used to produce films without any hydrogen (Xu et al., 2006). Because hydrogen-free diamond-like carbon coatings films exhibit greater thermal stability than their hydrogenated counterparts, as well as the fact that sputtering is a very useful tool for studying the effects of the addition of foreign elements or dopants on the film properties, this is significant. Dc and RF magnetrons are two of the most popular sputtering system configurations. However, due to the low carbon sputtering yield, the low deposition rate is the main drawback in the deposition of carbon films. Numerous modified systems are therefore employed to overcome this limitation. Unbalanced and closed field unbalanced magnetron systems, middle frequency magnetron sputtering, and ion beam sputtering are a few examples of these systems. Illustrations of these systems. The use of positive ion bombardment to affect film chemistry and atomic order, from which all other film properties are derived, is one of the features shared by sputtering techniques that are similar to other methods, such as Plasma-enhanced chemical vapor deposition. The temperature of the substrate and the amounts of applied power (dc, rf, etc.) have 4 significant impacts on this. The flow of neutral particles and ions as well as the plasma's reactivity are both impacted by the power being applied during the growth process (Roy et al., 2008). Substrate biasing, which is said to improve the properties of the films, has also been the subject of extensive study by other researchers. Carbon nitride can also be deposited thanks to sputtering. In most cases, this denotes the use of precursor gas, allowing for the incorporation of these elements through the discharge plasma's reactivity. Sputtering enables the synthesis of CNx films without hydrogen, which could result in the production of hard film coatings. Graphite-like CNx films with control cable sp3 content, low-stress levels, and nanoporous, nanocolumn, and nano-structured films have recently been demonstrated to be possible using this method (Fortunato et al., 2004). These sputtering techniques appear to be constrained in terms of flexibility when depositing different structured films, particularly for tabular nanostructures like CNTs, nanofibers, etc.

1.4 spray pyrolysis method

Spray pyrolysis is a processing technique, being considered in research to prepare thin and thick films, ceramic coatings, and powders. Spray pyrolysis is a very straightforward and reasonably affordable processing technique, in contrast to many other film deposition techniques (especially regarding equipment costs). It offers a remarkably simple method for setting up films of any composition. High-quality chemicals or substrates are not necessary for spray pyrolysis. The technique has been used for the production of powder as well as the deposition of dense and porous films. Using this adaptable method, even multilayered films can be produced with ease. For many years, the glass industry and the manufacture of solar cells have employed spray pyrolysis (Krishnakumar et al., 1987). An atomizer, precursor solution, substrate heater, and temperature controller make up the typical spray pyrolysis apparatus. Spray pyrolysis typically employs one of the following atomizers: air blast (the liquid is exposed to a stream of air), ultrasonic (ultrasonic frequencies produce the short wavelengths required for fine atomization), or electrostatic (the liquid is exposed to a strong electric field) (Quaranta et al., 1993). There have been many reviews of spray pyrolysis methods published. Mooney and Radding have reviewed the spray pyrolysis process, specific films (especially CdS), the application of devices, and the properties of the deposited films in environmental conditions. The creation, characteristics, and use of sprayed films in solar cells, anti-reflection coatings, and gas sensors have all been covered by Tomar and Garcia (Amalina et al., 2012). A review of the tools, operating guidelines, and optoelectronic materials deposited by the spray pyrolysis method was presented by Albin and Risbud. Pamplin has written a review of spraying solar cell materials and compiled a list of sources on the spray pyrolysis process. Patil recently reviewed thin 5 metal oxide and chalcogenide films created by spray pyrolysis and various atomization methods.

1.5 Spin coating method

The simplest technique for creating a thin film on a substrate is spin coating. The material to be deposited is diluted in a solvent before being spun onto a surface. The solution is then applied to the substrate surface. The wafer is then spun rapidly. Surface tension, solution viscosity, and spinning speed all affect the film's thickness. The solvent is partially eliminated during the spinning process by evaporation and partially through subsequent baking at high temperatures. A substantially planar surface is produced by spin coating. Spin-coating has been used to create dense, oriented ZnO thin films of the highest quality. One potential use for ZnO TFTs is as transparent select transistors in each pixel of an active-matrix liquid-crystal display (AMLCD). They could also be used as transparent replacements for organic thin-film transistors or amorphous silicon in other appropriate applications (TFTs). The magnitude of the electron channel mobility is a critical indicator of TFT performance in these kinds of applications. More applications are possible as a result of increased mobility because it causes higher drive currents and faster device operating speeds (Wager et al., 2003). By utilizing a spin coating and spray pyrolysis techniques, this report predicts the likelihood of fabricating high-performance thin film transistors at room temperature. The anhydrous zinc acetate in distilled water, however, was used in our project work to create the transparent thin film.

2. Results and Discussion

Diagonal resistance and average sheet resistance of different ZnO thin films used for making a channel of TFT by using a spin coating method are presented in table 1.

Table 1: Diagonal resistance and average sheet resistance of different ZnO thin films used for making a channel of TFT

by using a spin coating method

S.N.	Sample Name	Diagonal Resistance (R1) Ω	Diagonal Resistance (R2) Ω	Average Sheet Resistance Ω/sq	Growth Temperature ^{0}C
1	F5	31.9	32.1	9.14	340
2	F57	31.3	34.2	9.42	340
3	F52	29.50	30.6	8.9	340
4	F1	31.0	30.4	8.7	340

Table 2: Diagonal resistance and average sheet resistance of different ZnO thin films used for making a channel of TFT using the spray pyrolysis method

S.N.	Sample Name	Diagonal Resistance (R1) Ω	Diagonal Resistance (R2) Ω	Average Sheet Resistance Ω/sq	Growth Temperature ^{0}C
1	F53	34.5	34.8	10.0	340
2	F39	35.7	33.4	9.92	340
3	F29	31.9	32.8	9.3	340
4	F2	33.4	33.1	9.5	340

From the above tables, we see a slight variation in the diagonal sheet resistances of the samples. Here the variation is not too large. Here, the variation is not very significant. Although they were prepared using the same procedure and the same parameters, some ZnO-coated samples during the work had high resistance as well. The resistance is extremely sensitive to even minute impurities and flaws, which explains why. Variations in resistance are caused by chemical impurities, unstable electric power, temperature swings, and nebulizer issues. We, therefore, grouped the samples with nearly identical resistances and used them in the current work to ensure greater accuracy of the results.

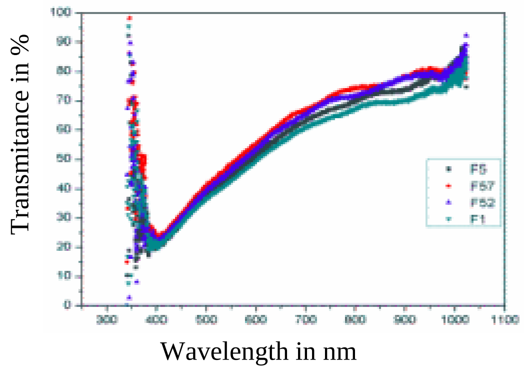

Figure 1: variation of transmittance with wavelength samples grown by a spin coating method.

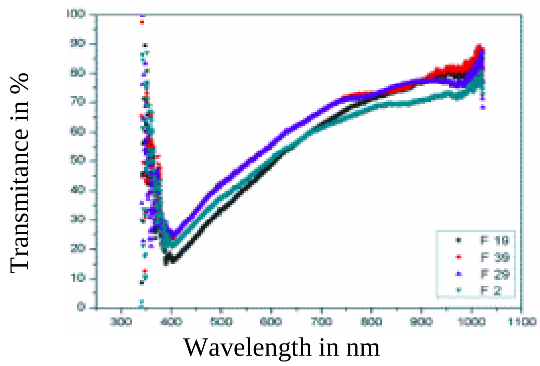

Figure 2: variation of transmittance with wavelength samples grown by spray pyrolysis method.

Fig 1 and Fig 2 show the variation of transmittance with the wavelength range 300 nm – 1050 nm. From the transmittance spectra, we see a slight variation in the transmittance spectrum compared to the transmission spectrum of films used for making a working channel of Transistors. As the variation in transmittance of different samples is not so high, we can say that the samples are reproducible. For the accuracy of the result, we have grouped the samples with different transmittance and the samples with nearly the same transmittance are used in this work.

2.1 Transmission Spectra

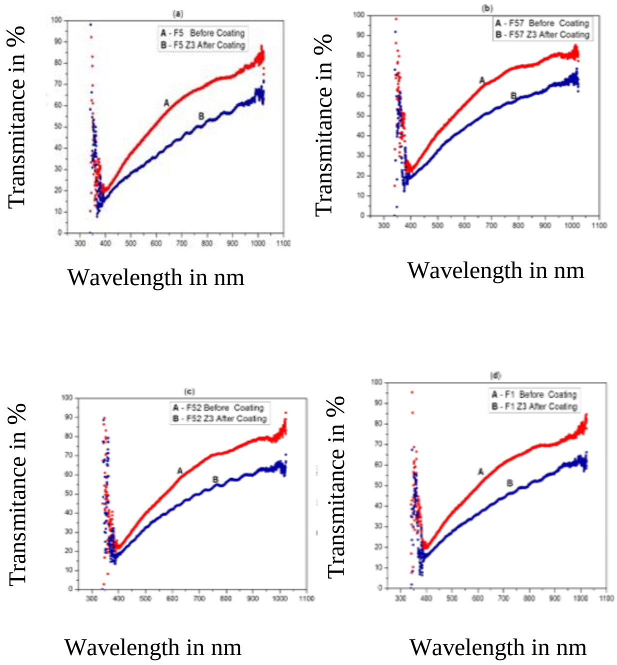

Figure 3: Transmittance of the samples before and after 3 coatings of ZnO seed layers the samples (a) F5 (b) F57 (c) F52 (d) F1

From the graphs, it is seen that the transmittance of each of the 8 samples decreases with 3 coatings of the ZnO seed layer. The decrease in transmittance of samples confirms the coating of the ZnO seed layer on it. Since the decrease in transmittance in all the cases is nearly the same, this shows the reproducibility of ZnO coats.

2.2 Absorption spectra

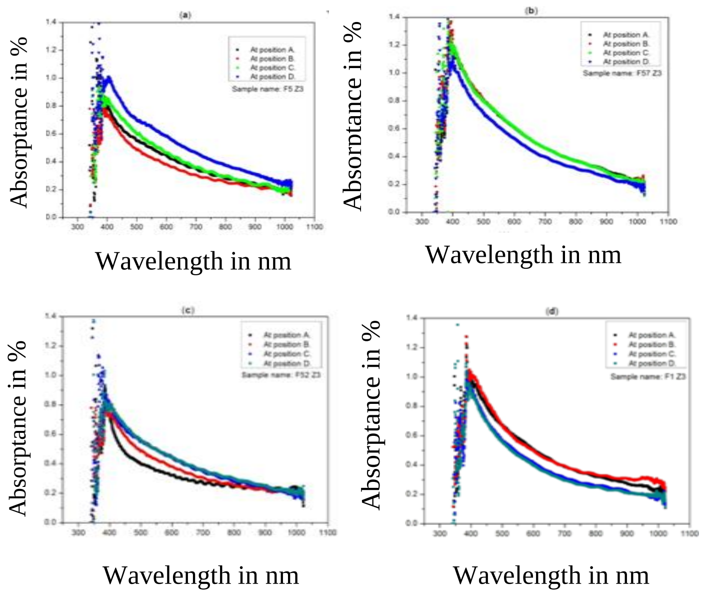

Fig 4: Absorption spectra at different positions of the ZnO nanostructure samples (a) F5 Z3 (b) F57 Z3 (c) F52 Z3 (d) F1 Z3

Almost all figures shown in Fig 4 depict that the absorption spectra for the same sample taken at different positions are not the same. It means ZnO nanostructured samples are not uniform. There are various reasons behind the nonuniformity of these samples. The non-uniformity may arise due to the roughness of the ZnO seed layer or it may be due to the problem to grow uniform nanostructure in our laboratory because our sample is relatively larger). Even though the samples are not completely uniform, we can make a comparative study between them. For this, the average of all four curves is taken.

3. Conclusion

This work has clearly shown that the transparent thin films can be fabricated by using the local techniques designed by locally available staff using less harmful chemical reagents like zinc acetate. Such fabricated films are found to be optically absorbing and transmitted in nature which further suggests that they can be used as a channel material in thin film transistors, contact lenses, cosmetics products, etc. Due to their excellent biocompatibility, economy, and low toxicity, the thin film transistor fabricated by ZnO is used in medical radiography, digital radiography, and active matrix displays.

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Conflicts of Interest

The authors report no conflicts of interest for this work.

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