Ultraviolet Photodetector based on Zin Oxide Thin Film Contacts

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Abstract:

This paper provides a general overview of the state of the art of ZnO thin film-based UV photodetector. It also discusses some recent UV photodetector based on ZnO thin film substrates developed in laboratory. The introduction section offers a background of the semiconductor thin film-based devices and their applications. The few papers have been reviewed for the fabrication of ZnO thin film by using different technique and found significant results for the application in UV photodetector.

Introduction

Thin film technology is a very important tools in last few decades for providing high quality interconnection in many electronics and optoelectronics devices such as a flat-panel, photo detectors and solar cells. Thin film technology is very efficient method for using the performing device application that take advantage of high performance include sensors, flat panel display, micro electromechanical system, (MEMS), biomedical device and coating optical instruments, microwave and other integrated circuits and thin film integrated passive devices (IPDS). Thin film technology can minimize the cost of devices with the materials wastage significantly [1-6]. It is very useful approaches which offers a wide variety of option in terms of designing and fabrication of devices. Different technique [7-9] have been used for the deposition of different layers e. g. contact, buffer, absorber reflector, etc. These techniques broadly can be classified into three groups physical vapor deposition (PVD), chemical vapour deposition (CVD) and chemical solution deposition (CSD). Due to its application in industries ultraviolet (UV) photodetector are attracting research for using thin film technology due to their potential application in industry. Photodetector based on semiconductor materials are replaced by photomultiplier tube (PMT) [4]. Silicon based photodetector can be used without involving any additional filters to block the undesired visible, IR radiation. In this paper, we have discussed and analysed the ZnO thin film technology for application in ultraviolet photodetectors. ZnO is very useful materials for the application point of view. It is a II-VI compound semiconductor oxide with wide bandgap and wurtzite structure has shown in figure 1 [7-9]. Zinc oxide crystallizes in two main forms, hexagonal wurtzite and cubic zinc blende. But they wurtzite structure is most stable at ambient conditions for research purpose. It has attractive and fascinating research efforts due to its unique properties and multifunctional application. ZnO is a remarkable semiconductor material relative to other wide bandgap semiconductor for UV photodetector application due to its very attractive properties such as good photo conductivity, easy processing at lower temperature, and good radiations, hardness and the possibility of integration with existing integrated microelectronics. In this paper, we have recently reviewed the application of ZnO thin film in UV photodetector. Many researchers have been studying the properties of ZnO nanoparticles and fabrication thin film for using as contacts in sensors, detectors and printed circuit, etc. In present scenario in technology in India as well as abroad many academician, engineer, physicists have been investigated the ZnO based thin film find immense application in many electronics and optoelectronics devices including sensors, detectors, actuators, transducers, UV light emitting diode and transparent thin film transistors. There are some attractive properties of the ZnO which make the material superior to the other wide bandgap for important electronics and optoelectronics applications are discussed in the following sections.

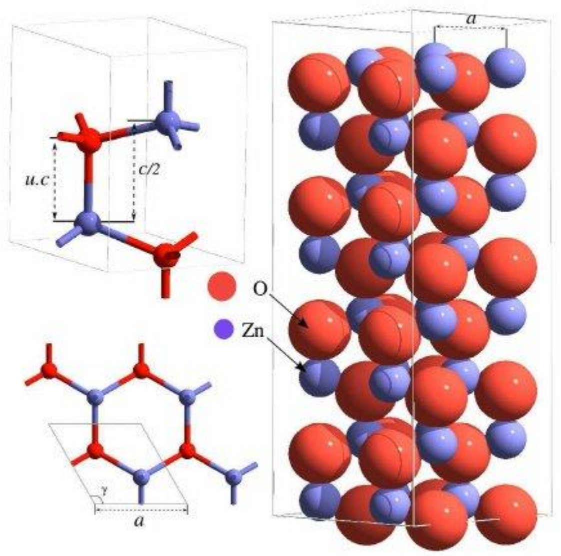

Figure 1. Bulk crystal structure of wurtzite zinc-oxide with bulk lattice parameters a = 3.25Å, c = 5.207Å, and u = 0.3825Å. In the bulk each ion is four-fold coordinated, while the surface atoms have only three-fold coordination.

Properties of ZnO thin film

ZnO is one of the most promising wide bandgap semiconductors with many interesting properties. The ZnO semiconductor has a hexagonal wurtzite crystal structure with lattice parameters a = 3.25Å, c = 5.207Å, and u = 0.3825Å. In the ZnO crystal unit Zn atom is tetrahedrally coordinated with four O atom, where the Zn d-electron hybridize with O p-electrons. The bonding between Zn atom and O atoms are highly ionic, due large difference in their electronegativity values)1.65 for Zn and 3.44 for O) [1].The Zn material exhibit an interesting combination of optical, semiconductors, piezoelectric and optoelectronics properties which makes is a very useful thin film material for both the electronics and optoelectronics devices. The most important aspect of ZnO material is a direct bandgap material with wide bandgap energy of ~ 3.4 ev and high excitation binding energy of ~ 3.0 ev can be achieved by doping ZnO with Cd^{2+} while Mg^{2+} can be used to increases the bandgap energy to ~ 4.0 ev. However, ZnO material is inherently n-type because of the lack of stoichiometry by the presence of native donor defects, hydrogen defects, oxygen vacancies and /or zinc interstitials. Some of these intrinsic defects act as shallow donors and reside approximately 0.01 to 0.05ev below the conduction band. In addition, n type conduction can be controlled by excess Zn atoms or by adding Al, Ga or In dopants. A number of thin film deposition techniques are used to grow ZnO thin films for the designing the optoelectronics and electronic devices. The most important advantage of the thin film growth is the ability of the material to grow as highly epitaxial films with minimal defects. Many researchers have prepared ZnO thin films using spray pyrolysis [10], molecular beam epitaxy (MBE) [11], metal organic chemical vapour deposition (MOCVD) [12], RF sputtering [13] and pulsed laser deposition (PLD) [14], hydrothermal method [15], thermal evaporation [16], sol gel method [17], chemical growth method [18] vapour liquid solid (VLS) [19], and etc. The electro-optical properties of the thin film are generally dependent on deposition conditions.

ZnO Thin-Film based UV Photodetectors

There exists a high demand for the designing of UV photodetector for research and commercial applications. UV detectors have been using in a variety of civil and military applications including chemical and biological analysis. Osorno et al. [20] have studied the optical and electrical characterization of ZnO thin films by using ultrasonic spray pyrolysis method. They have found a very remarkable thin film with higher crystallinity and greater absorption. Thin film was characterized by AFM, SEM and XPS. The ZnO thin films surface with and without annealing have shown in figure 2. Figure 3 shows the SEM image for thin film surface where a granular morphology with well-defined grain boundary. These significant results for application very important for the ZnO thin films-based photodetectors.

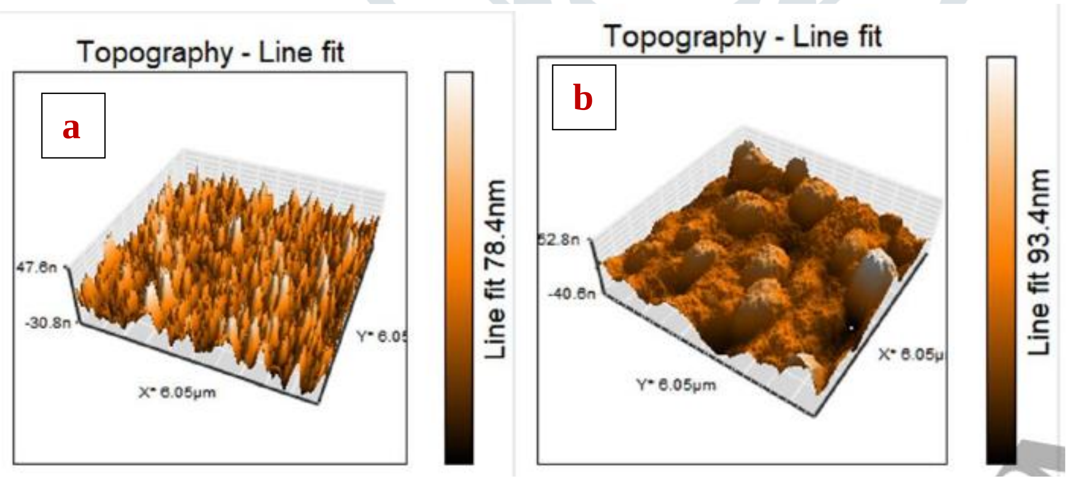

Figure 2. AFM images of ZnO films without (a) and with (b) annealing. The grain is less than 300 nm for the no annealing film, while for annealed films the range goes from 1.5 to 2 µm.

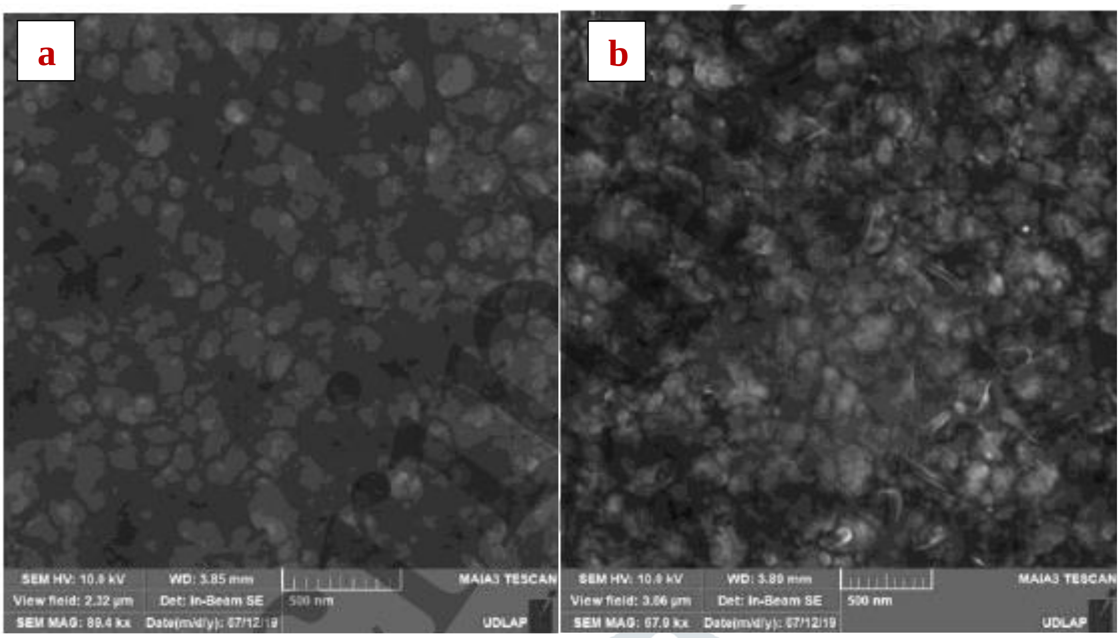

Figure 3. SEM micrographs of ZnO films without (a) and with (b)annealing. Well-defined grain boundaries are seen from the sample without annealing, whereas the film with annealing presents anagglomeration of several grains and no longer distinguishable grain boundaries.

A very promising application of spray pyrolysis technique is the preparation of multifunctional doped ZnO films with a porous structure. The doping can be achieved by including an additional doping precursor within the synthesis solution, such as aluminium chloride, tin chloride and silver nitrate. This method was demonstrated to successfully dope porous ZnO with various elements, including Al [21, 22], Sn [23], Ag [24], Na [25], Mg [26] and many others [27, 28]. The pristine ZnO and doped with different element structure were found to be designing of the gas sensors. Different types of UV photodetector can be used to deigning ZnO thin film for different techniques during last decades. These also includes photoconductive, avalanche, Schottky barrier and p-n junction etc. Murali et al. [29] have placed the ZnO thin film on glass substrates by thesol-gel technique by using acrylamide route from zinc chloride, acrylamide, bisacrylamideand ammonium persulphate. Through adding ammonia solution, the pH of the zinc chloride solution was increased to 9 followed by the addition of acrylamide and bisacrylamide while the temperature of the precursor mixture was maintained at 70°C. A small amount of gelling agent ammonium persulphate has been added until a viscous solution has been formed. The sol-gel process is very simple, and it enables one to have the control over doping concentration. Many researchers have been using the preparation ZnO thin film on glass substrates. In this technique we can easily control the thickness of the ZnO film. Due to its simplicity and advantages over other thin film deposition techniques Sol-gel is a commonly used technique for manufacturing ZnO films in recent years. The first and most critical prerequisite for this process in the production of ZnO film is an acceptable source option for Zn.

Conclusions

In this review paper, we have discussed the basic properties ZnO thin film for electronics and optoelectronics such as sensor, detector display devices. The main goals of the designing and fabrication the ZnO thin film for the application of UV photodetector. The surface morphology, surface states, chemical reactivity of the metal to the ZnO surface have been review in this paper. We have also studied the optical and electrical properties of ZnO materials which a material becomes more electrically conductive due to the absorption of electromagnetic radiation such as visible light, UV, infrared light or gamma radiation.

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