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Short Communication

A Short Note on Zno Based Optoelectronics Devices

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Abstract

Zinc oxide (ZnO) has lots of potential for making optoelectronics devices owning to its direct band gap energy of 3.37eV, band gap tailoring and recent reports on achieving p-type conductivity. Various different properties associated with it such as conductivity, piezoelectricity and biocompatibility makes it suitable for designing different type of sensors. This report provides a short introduction on different devices and sensors made using this material and their different applications in various fields.

Introduction

There has been tremendous growth and interest in Zinc oxide based optoelectronics devices such as laser diode, light emitting diode (LED), solar cells and photo detectors, since last few decades. ZnO because of its large direct band gap energy of 3.37eV and large exciton binding energy of 60meV is gaining lots of attention for making these devices [1]. The band gap energy of ZnO can be tailored using properly alloying it with different elements. Adding Be and Mg increases its overall band gap energy while adding Cd decreases its band gap energy [2]. This in term provides a way to create barrier layer and quantum well structure in optoelectronics devices.

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The availability of ZnO substrate in larger area and easiness in performing wet etching during the fabrication process has another advantage over the other counterpart materials used for making these devices. Naturally occurring ZnO is n-type semiconductor while making it p-type semiconductor is difficult task. Hence initially various devices based on n-ZnO suitably deposited over various p-type semiconductors were made [3]. Various p type materials such as Si, GaN, AlGaN, NiO, SiC were used with n-ZnO to form a p-n junction structure.

However considerable efforts are being made to make ZnO p-type by adding certain impurities doping. There are various techniques which are being employed to make p-type ZnO. One of the ways is to use donor-acceptor codoping method such as In-N, Al-N and Ga-N [4,5]. Still lots of works are going on theoretically and experimentally to get very efficient p-type ZnO. Once we have both n-type and p-type ZnO it becomes easier to make LED using this material, as existence of both p and n type conductivity is essential requirement for making any LED. While designing the different devices we have the freedom to choose number of layers, their constituent materials and thickness. All these parameters had a direct impact on the final outcome of the device. So before going directly to the fabrication process, it becomes essential requirement to study numerically the behavior and performance of the device by changing one parameter at a time keeping all other parameters constant.

Double heterostucture LED's based on ZnO has been described in various literature. Extensive research is going in this area to make LED having high efficiency as compared to existing LED made using III-N materials. Arsenic doped BeZnO and ZnO layers were grown by hybrid beam deposition to make LED having peak electroluminescence at 363 and 388nm [6]. CdZnO active layer sandwiched between antimony (Sb) doped p-type ZnO and n-type gallium (Ga) doped ZnO fabricated using dual ion beam sputtering deposition system has shown electroluminescence emission at around 446nm which falls under blue color of visible spectrum regime [7]. Also ultra violet and blue LED's made using InGaN are easily available, highly efficient but green LED's performance still remain low for use in solid state lighting [8]. Hence green LED based on ZnO is gaining lots of attention because of its advantages over the traditional one made using InGaN.

The other list of optoelectronics device that can be made using ZnO are photodetectors, which converts light photon into current. Because of strong radiation hardness, high chemical and thermal stability in harsh environment of ZnO makes it a suitable candidate for making photodetectors. Also efficiency of Si based photodetectors is low and they degrade in very short span of time. Ultraviolet photodetectors can be designed using properly alloying Mg with ZnO for different cut-off wavelengths [9]. These photodetectors finds lots of applications in civil and military areas. An n-type ZnO and nanotubes and p-type silicon heterstucture is fabricated and is tested successfully under UV illumination. This process after growth allows direct integration of high quality 1d structures without doing any post processing damage such as ultrasonic vibrator, fluidic dispersing and chemical erosions [10].

Zinc Oxide based solar cells are the other list of devices that is of so much importance because of their advantages related to environmental and energy problems. ZnO nanostructures are used as a photoanode in the fabrication of dye-sensitised solar cells (DSSC). Thin films nanostructure made using ZnO offers large surface area, direct electron path way and effective light scattering centre [11]. ZnO acts as a substitute for TiO2 for making DSSC. ZnO has much higher electron diffusivity, low cost with respect to TiO2 and is stable against photo-corrosion. Also it has a higher electron mobility of 115-155cm2V−1s-1 which favors efficient electron transfer in semiconductor and reduces the recombination rate making solar cell more efficient [12].

Also different types of sensors such as gas sensors, pressure sensors, chemical sensors, biochemical sensors etc. can also be designed employing the various characteristics of ZnO. For example ZnO can be used as a pressure sensor because of its piezoelectric nature where change in stress can produce change in electric potential. Biocompatibility and nontoxicity of ZnO helps it to be used it as biochemical sensors. Gas sensors are based on the change in the conductance of ZnO by the presence of reactive gases. These sensors have very high sensitivity and very low detection limit that helps these sensors to be used in different fields for different applications.

Light weight gas sensors having sensitivity upto parts per million (ppm) operating at low power can be designed using ZnO. Different gases such as NO2, NH3, NH4, CO, H2, H20, O3, H2S and C2H5OH are detected by measuring the resistive change in nanocrystal line ZnO films [13]. Also different biological molecules can be detected using nanosized biosensors developed by ZnO nanostructures. Electrical biosensors based on functionalized ZnO nanorods with biotin are fabricated for highly sensitive detection of biological molecules. Streptavidin binding down upto concentration of 25-nM is being detected using ZnO nanorod which is more sensitive than the previously electrical biosensors made using Si nanowire and carbon nanotube FET sensors [14].

Hence ZnO based devices are gaining lots of attention nowadays and too much research is going in this field to increase the overall efficiency of these devices. It is progressively replacing traditional materials for making these devices, with lots of advantages over them. Different mechanisms of fabrications are being used and are under the continuous area of study to get the best possible performance from these devices.

Conclusion

Various optoelectronics devices based on ZnO such as LED, laser diode, photodiode and solar cells are being made utilizing the various different suitable properties offered by ZnO for these devices. Different types of small sized sensors are also being designed using this material which consumes very less power for operation, with very high sensitivity and suitable performance with respect to their counterpart sensors. Evidently this short note reviews only some of the research papers in this field and many exciting works have not been cited. So this short discussion is an indication of ZnO being used as active materials for fabrication of so many optoelectronics devices with superior performances. Hence ZnO has a very promising future in the field of designing and fabricating many more devices with better outcomes.

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