Chapter

Introductory Chapter: Overview of ZnO Based Nano Materials and Devices

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1. Introduction

This chapter presents an introductory review about ZnO nanomaterials and nanodevices. ZnO as a wide band gap semiconductor has received a great attention in many research areas. This is due to the electrical, optical and structural properties of the ZnO. These properties make ZnO as one of the major contenders for many photonic applications. ZnO has distinguished electrical and optical properties. ZnO is considered as a potential contender in optoelectronic applications such as solar cells and ultraviolet (UV) emitters. The nanostructured ZnO material has many applications in the area of nano based devices. The UV light can be absorbed by the ZnO based nano material. This can be used in several optical applications. Currently, the nano structures based on ZnO materials devices have attracted attention due to their wide range applications.

2. ZnO properties

ZnO is classified as a negative (*n*-type) semiconductor material as grown. ZnO is one of group 2–4 semiconductor materials. ZnO has a band gap of 3.37 eV. ZnO also has a high binding energy. The ZnO binding energy is about 60 meV [1]. The ZnO material has a high exciton binding energy and high thermal stability [2]. It also has a high optical gain [2]. These properties made ZnO as one of the most interesting materials for electronic and optoelectronic based devices. On the other hand, the ZnO's high binding energy permits the fabrication of several photonic devices with a high optical efficiency [3]. Also, the short wavelength optoelectronic devices are being made based on ZnO's wide band gap [3].

ZnO is a transparent optical material suitable for the visible wavelength region [4]. ZnO is also one of the potential materials for optoelectronic applications [5–7]. The ZnO's characteristical properties were investigated by many research groups. That leads to the improvement of the electrical and the optical properties of ZnO. Many other properties of ZnO allow variety of applications. These applications include photovoltaics, LEDs, photodetectors, and microelectromechanical systems (MEMs) [8–12].

3. ZnO crystalline structure

ZnO normally has a hexagonal structure. The Zinc atoms are tetrahedrally coordinated to four oxygen atoms [13]. Moreover, there are two crystalline structure of ZnO. These structures are the wurtzite and the Zinc-blende. These two structures

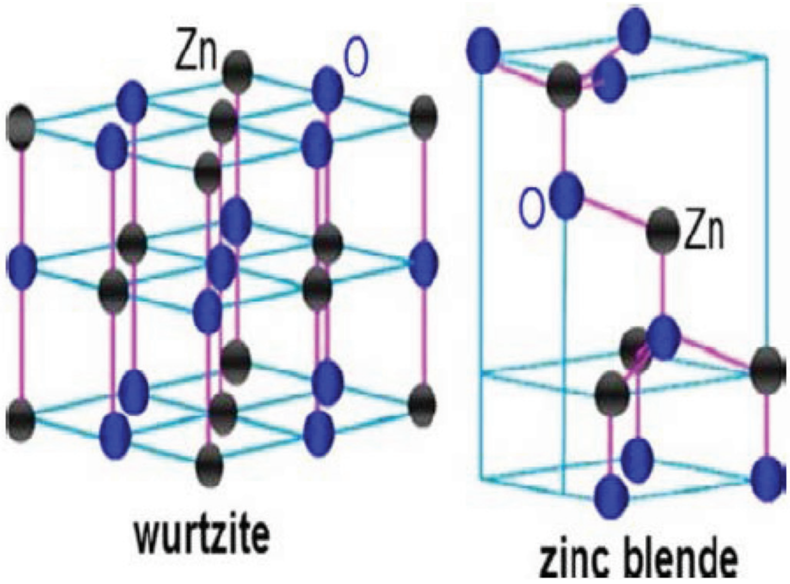

Figure 1.
ZnO different crystalline structures [3].

of ZnO lead to a perfect polar symmetry along the hexagonal axis of the ZnO's crystalline structure. The ZnO based piezoelectricity and spontaneous polarization are due to these crystalline structures. The two ZnO's crystalline structures are shown in **Figure 1**.

4. ZnO doping

Generally, the doping process is used for enhancing the electrical and the optical characteristics of the material [14]. The undoped *n*-type ZnO is usually due to the oxygen vacancies in the ZnO structure [15, 16]. This makes the doping process of ZnO as *p*-type is very difficult. There are several *p*-type dopants for ZnO nano materials. Lithium is one of the *p*-type dopants for the ZnO. It takes a centered position by replacing the zinc atoms in the wurtzite structure of the ZnO [17]. GaN can be used

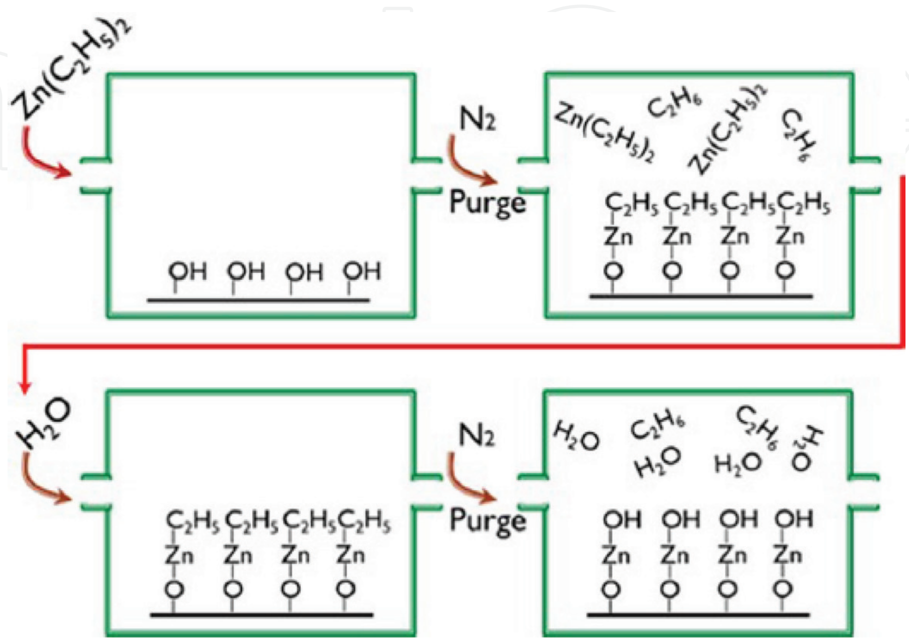

Figure 2.
ZnO doping process [25].

with ZnO to bypass the problem of *p*-type doping of ZnO nano material [18]. GaN is a wide band gap semiconductor with very similar lattice constants to ZnO. The GaN *p*-type dopant is commonly made with magnesium [18]. Several research groups have reported on the fabrication of ZnO hetero-junction devices. These hetero-junctions devices used materials like silicon [19], aluminum gallium nitride [20], and gallium nitride [21] for the *p*-type semiconductors. The electrical resistivity is significantly decreasing for ZnO by using doping elements like aluminum [22], gallium [23], and indium [24]. The ZnO doping process is shown in **Figure 2**.

5. ZnO nanostructured material

Recently, several efforts have been made for developing the ZnO film in different nanoshapes. These nanoshapes include the nanorods, nanowires, and nanocubes [23–26]. These nanoshapes of ZnO films can be used in several applications including the UV laser emission, photodetector and LEDs devices.

The nanoshapes of ZnO nanowires and nanorods based devices are becoming an important part of many potential applications. These applications include the optoelectronics, electromechanical nano devices [27] and biosensing [28].

There are several applications were reported based on ZnO based nanomaterials. These applications include the transparent electronic devices [29], the UV light emitters [30], the piezoelectric devices [31], the p-n junction devices [32], the field effect devices [33], the sensors [34], the optoelectronics [35], and the field emission devices [36].

6. ZnO nanowires based devices

ZnO nanowires based devices have many research interests. Recently, many devices based on ZnO nanostructured nanowires were reported. This is due to the high surface area and the low cost of fabrication [37–40]. There are several fabrication methods being used for the growth of the ZnO nanowires. These methods include the vapor liquid solid [41], metal organic chemical vapor deposition [42], chemical bath deposition [43] and hydrothermal method [44] with varied film qualities. The ZnO nanowires image is shown in **Figure 3**.

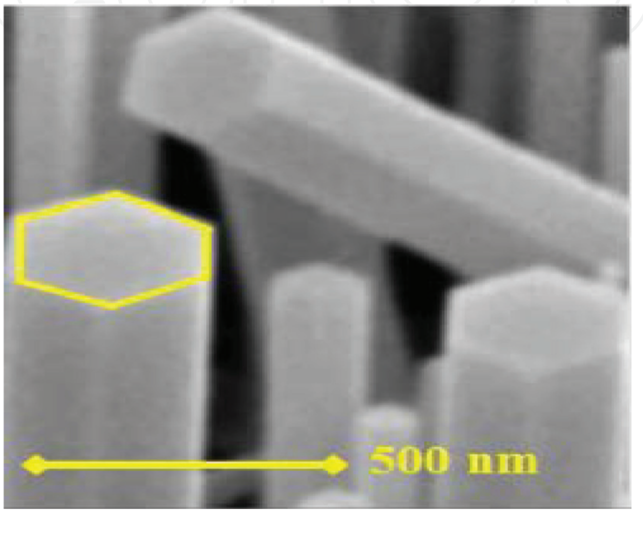

Figure 3.
ZnO nanowires [45].

7. ZnO nanorods based devices

ZnO based nanorods have received a good interest in various optoelectronic nanoscale devices. These devices include the photovoltaic cells, UV laser diodes [46], LEDs, optical sensors, and UV photodetectors [47]. Several applications based on ZnO require a large surface area. The simplest method to increase the surface of the ZnO layer is by growing nanorods. The larger the surface area the more photons are expected to be absorbed by ZnO layer [48]. One way to improve the crystalline structure and the photoluminescence spectra of ZnO nanorods is by annealing process [48].

The ZnO nanorods are being fabricated using several methods. These fabrication methods include the hydrothermal method [49], metal oxide chemical vapor deposition method [50], pulsed laser deposition method [51], aqueous solution method [52]. In these methods, the surface morphologies, optical and electrical properties of ZnO nanorods are depending on the fabrication parameters. These parameters include the deposition time, temperature, and post deposition annealing. The ZnO nanorods are shown in **Figure 4**.

Other fabrication methods of the ZnO nanoshape films are including the sol-gel technique, RF magnetron sputtering, electron beam evaporation, spray pyrolysis (SP), and molecular beam epitaxy, electrochemical deposition [54]. The electrochemical deposition wet method is a well-established solution based process to obtain ZnO nanoshapes thin films [55]. It has many advantages including the low cost and the temperature deposition over other types of fabrication.

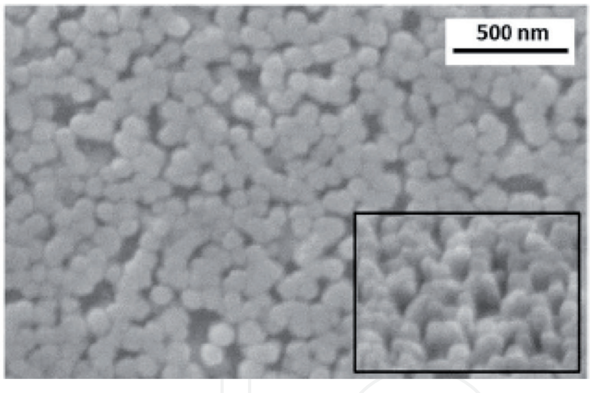

Figure 4.
ZnO nanorods [53].

8. ZnO nano based applications

The ZnO material is being used for many optoelectronic based devices applications. These devices applications include the varistors, sensors [13, 56–59], optical wave guides, UV light emitters [60], LEDs [61], micro-electro-mechanical systems [12], spin electronics [62], solar energies [63], p-n junctions [64], field effect and emissions [65–67], displays [68], acoustic waves [69], and solar cells [6].

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