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Overview on Zno and Its Applications: A Glimpse

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ABSTRACT:

In several scientific areas, ZnO as a wide band gap semiconductor has gotten a lot of attention. This is owing to ZnO's electrical, optical, and structural capabilities, which make it a strong competitor for a wide range of photonic applications. The electrical and optical properties of ZnO are distinct. In optoelectronic applications such as solar cells and ultraviolet (UV) emitters, ZnO is being investigated as a possible contender. The nanostructured ZnO material offers a wide range of applications in nanotechnology. UV light can be absorbed by the nanomaterial made of ZnO. This can be applied to a wide range of optical applications. Nanostructures based on ZnO materials devices have recently gotten a lot of attention because of their wide variety of applications. This article highlights about the overview on ZnO and its applications.

Keywords: ZnO, Properties, Applications

INTRODUCTION:

Metal oxide (MO) semiconductors are among the most widely available materials on the planet. Unlike traditional group-IV inorganic semiconductors such as silicon and germanium, their structural, electrical, and optical properties have piqued the interest of many researchers around the world, and significant advances in both technological and industrial applications have been reported in recent years. (Zhao et al., 2009) The band gap of these materials can be modified to display metallic, semiconducting, and insulating properties. ZnO has been widely employed in optoelectronic devices due to its low toxicity, thermal stability, great oxidation resistance, large specific area, and high electron mobility (Fai et al. 2007).

PROPERTIES OF ZnO:

ZnO has a hexagonal wurtzite structure in which each cation is surrounded by four anions and vice versa.

Non-centrosymmetric ZnO structures are one of the most essential qualities that make ZnO suitable for piezoelectric and pyroelectric applications because of its tetrahedral coordination structure (No et al. 2006; Zhang et al. 2009). ZnO is a potential photonic material for ultraviolet and blue devices such as short wavelength light emitting diodes and laser diodes in optoelectronics because of its broad direct bandgap (3.37 eV) and high exciton binding energy (60 meV) at room temperature.

Because of the existence of native defects including oxygen vacancies and zinc interstitials, intrinsic ZnO shows n-type material properties (Wang et al. 2012). As can be seen in table 1, the ZnO has a number of unique features.

Table 1. Physical Properties of Zinc Oxide

Molecular Formula	ZnO
Molar Mass	81.408 g/mol
Appearance	White solid
Odour	Odourless
Density	5.606 g/cm^3
Melting Point	1975°C
Boiling Point	2360°C
Solubility in Water	0.16 mg/100 mL (30°C)
Bandgap	3.37 eV
Refractive Index	2.0041

Structural Properties of ZnO:

Crystals of ZnO may form in three distinct shapes: hexagonal wurtzite, cubic zinc blende, and cubic rock salt, the latter of which has a cubic structure (Labs, 1947; Li et al. 2012). Structures like wurtzite are the most frequent, and they have the best operating stability. The wurtzite structure of ZnO crystallises at ambient pressure and temperature. There are two Zn2+ and O2 sublattices in the P63mc hexagonal lattice, which are connected by two interconnecting sublattices. This means that each Zn2+ is connected to four Zn2+ and each O2 is connected to four Zn2+. a = 3.2495, and c = 5.2069 are the hexagonal unit cell's lattice parameters (Lide, 1992).

Optical Properties of ZnO:

There are several uses for ZnO in UV-visible optoelectronic devices, such as LEDs, photodetectors, and solar cells, because of its broad direct band gap and strong exciton binding energy at room temperature (Fa et al. 2007; Husna et al. 2012; Lei et al. 2012; Mandalapu et al. 2006). At normal temperature, ZnO's large free exciton binding energy benefits from efficient excitonic emission. The ability to tune the band gap of a semiconductor is critical for device development, especially for optoelectronic applications, and ZnO meets this criterion with ease. It is possible to increase the optical transparency of ZnO thin films to over 80% by tweaking the process parameters used during the deposition process (Kao et al. 2012; Netrvalova et al. 2012). To be used as a TCE in thin film solar cells, this quality is a must.

Electrical Properties of ZnO:

ZnO's electrical characteristics are difficult to measure because of the considerable variation in the quality of bulk samples. The n-type electrical property of ZnO is due to the existence of native defects, such as oxygen vacancies and zinc interstitials. In 1990, Van der Pol hypothesised that Zn interstitial, the major native shallow donor, was responsible for the native n-type conductivity (Ashok & Muthukumaran, 2015; Kim et al. 2013). Undoped ZnO thin films have a carrier concentration of 1016 cm-3 and a conductivity of 101 S/cm. ZnO doped with Al and Ga may achieve carrier concentrations of the order of 1020 cm-3 and conductivity on the order of 104 S/cm. As Transparent Conductive Oxide (TCO) materials for diverse optoelectronic applications, doped ZnO thin films have been extensively investigated (Sulyanov, 2008; Yan et al. 2013).

Chemical and Mechanical Properties of ZnO:

Due to its thermo chromatic feature, pure ZnO is generally white in appearance, but when heated over 300°C, its colour changes. Zinc carbonate is formed when ZnO is exposed to air and then absorbs carbon dioxide. In water, ZnO has a weak solubility; however, in acids, it is soluble. Zinc sulphate is the product of its interaction with sulfuric acid. When zinc reacts with alkali metals, zincate is formed (Klingshirn, 2007; Wiberg 2001; Li et al. 2012).

An very bendable material with a hardness of less than five gigapascals is ZnO. Heat capacity, heat conductivity, limited thermal expansion and high melting temperature make ZnO an excellent material for heat storage. Mechanically, ZnO possesses excellent piezoelectricity, which makes it an ideal semiconductor for use in electromagnets and other high-frequency applications (Fan & Lu, 2005; Wang, 2004).

Defects and Effect of Doping on ZnO:

ZnO is an essential material because of its ability to be used in a wide range of optoelectronic applications because of its multifunctional features. A crucial need for many applications is to improve and regulate the electrical and optical characteristics of ZnO by doping with different elements (Chang et al. 2010; Kang et al. 2006). Due to the lack of oxygen and Zinc interstitials, the as-grown ZnO is n-type. Al, Ga, or In may be used to dope it to adjust its n-type conductivity (Park et al. 2009; Shtereva et al. 2008; Sulyanov, 2008). Co, Mn, and other transition metal doped ZnO based Dilute Magnetic Semiconductors (DMS) have been examined to be suitable candidates for room temperature ferromagnetism and large magnetization (Morkoç & zgür, 2009). Rare-earth metal ion doping of ZnO may be used to tailor its emission characteristics in the ultraviolet and visible ranges, which is useful for a wide range of applications, including multi-color emission in light emitting devices (Lei et al. 2012).

APPLICATIONS OF ZnO:

Optoelectronic devices, sensors, transducers, catalysis, and medicinal devices all benefit from the unique properties of ZnO thin films and nanostructures. It was Wang (2004) who first proposed this idea. Unlike other materials, ZnO shows both semiconducting and piezoelectric qualities. Hydrothermal processes and chemical vapour deposition (CVD and PVD) are used to generate ZnO thin films and structures (nanorods, nanoflowers, nanoflakes, nanowires, nanobelts, nanocages, nanocombs, and nanosprings).

ZnO Thin Films as Transparent Conducting Oxide Material:

Thin ZnO films degenerately doped with elements of group III have been studied as an electronic material for many decades. All of the thin-film solar cells now on the market use ZnO films with doped ZnO layers. The cost-effective deposition methods and large-scale fabrication of these films have made them an alternative Transparent Conducting Electrode (TCE) in hydrogenated amorphous silicon (a-Si:H) thin film solar cells. Many attempts are being made to generate high-performance doped ZnO thin films that are both transparent and conductors, which is the main problem (Minami, 2013). ZnO also offers other optical capabilities, such as light scattering and subsequent light trapping, and it also boosts the reflection of unabsorbed light when utilised as a back reflector in a solar cell device at the back contact (Chen et al. 2012; Heo et al. 2014). Adding trivalent dopants like aluminium or gallium results in very high doping levels with carrier concentrations of up to 2 1021 cm-3 and resistivities of as low as 10-4 cm. As process technologies improve, ZnO films with better opacity, electrical conductivity, and structural integrity might lead to greater efficiency in the production of solar cells.

Luminescence Applications:

When measured at normal temperature, ZnO has a direct bandgap of around 3.37 eV and a significant exciton binding energy of 60 meV, which is substantially higher than the GaN often employed in solar cells (25 meV). The substantial binding energy of excitons at normal temperature ensures an effective emission of excitons under low excitation energy. As a consequence, ZnO has been identified as a possible photonic material in the UV-Blue range. Single crystalline ZnO nanowires have been proved to be capable of emitting UV light under ambient conditions. Overall, the PL spectra of ZnO nanostructures recorded with the Photoluminescence system indicate a high UV emission around 386nm, and a very weak emission in the visible range. The near-band edge emission of ZnO's broad bandgap must be accounted for by the UV emission, whereas the visible emission corresponds to the singly ionised Oxygen vacancy in ZnO and occurs from the recombination of a photogenerated hole with the defects (Gong et al. 2007).

Photocatalytic Applications:

Light energy may be used to initiate oxidation and reduction processes that remove persistent and harmful organic chemicals and microbes from water through photocatalysis. Material surfaces are subjected to both an oxidation and a reduction process owing to the photo-induced positive hole and negative electrons, respectively, when they are used as a catalyst (Li et al. 2016, Fugishima et al. 2008). ZnO is a viable contender for environmental applications because of its high oxidation ability and the fact that it possesses a straight and broad band gap in the near UV area. Its substantial exciton binding energy makes it possible for exciton emission processes to continue above room temperature. This is in addition to the fact that ZnO is a non-toxic and safe substance for the environment. Large-scale water treatment facilities may benefit from its compatibility with live organisms and low cost (Bu et al. 2013).

CONCLUSION:

ZnO is a compound semiconductor with a tehrahedral bonding configuration, where each anion is surrounded by four cations at the corners of a tetrahedron, and vice versa, corresponding to the sp3 covalent bonding. ZnO nanoparticles have also been considered to have antibacterial properties through photo induced oxidation process. Several metals combined with nanoforms of ZnO have been studied and have shown positive results in inactivating bacterial cells.

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