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Application Analysis of Zinc Oxide Nanomaterials Based on Economical Reduction in Energy Environment

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Abstract. The development of modern industry has not only created tremendous material wealth, but also paid tremendous resources and environmental costs. The problem of energy and environment is one of the main problems facing mankind at present. With the help of the photoelectric properties of ZnO nanomaterials, the applications of ZnO nanomaterials in energy and environment are explored. It is of great significance to the sustainable and coordinated development of energy and environment. Nano-zinc oxide is a kind of widely used nano-materials. Zinc oxide (ZnO), as a direct wide band gap semiconductor, is an environmentally friendly material with high exciton binding energy. New development models and requirements have been continuously upgraded to the level of sustainable development of human society. The structure and preparation of ZnO are briefly introduced in the structure of ZnO nanomaterials. Based on this, the application of ZnO nanomaterials in energy and environment is discussed.

Keywords: Energy Environment, Zinc Oxide, Nanomaterials.

1. Introduction

With the rapid development of science, technology and economy, human society has entered a new stage. The development of modern industry has not only created tremendous material wealth, but also paid tremendous resources and environmental costs [1]. With the increasing cost of energy and environment, people pay more and more attention to energy and environment issues. New energy sources have attracted more and more research attention. Zinc oxide (ZnO), as a direct broadband gap semiconductor, is an environmentally friendly material with high exciton binding energy [2]. Nano-ZnO is a widely used nanomaterial. The modified material as the electrode of the electrochemical sensing platform can not only effectively avoid the adsorption damage to the electrode. Moreover, the modified electrode has the advantages of rapid reaction, wide measurement range and good stability [3]. The concept of human social progress that takes into consideration the environment, friendly coexistence, and harmonious development is increasingly resonating with people.

The nano-materials can be used as structural units to construct nano-materials with specific shapes and sizes through structural design. The study of ZnO can be traced back to the 1930s or even earlier, and people's enthusiasm for research has been rising for decades [4]. With the development of nanotechnology, especially the emergence of various advanced preparation methods and many high-precision characterization instruments. The research on ZnO began to focus on crystal films, nanoparticles, nanowires, quantum wells and quantum dots. Crystal growth process is relatively simple,



cost is low, and the structure is diverse and controllable [5]. As a wide bandgap semiconductor, ZnO has a wide conductivity bandwidth, high electron excitation binding energy and optical gain coefficient, good chemical stability and biocompatibility at room temperature [6]. The new development model and requirements have been continuously raised to the height of sustainable development of human society.

2. Characteristics of Nano Zinc Oxide

Zinc oxide crystals have three structures: hexagonal wurtzite, cubic sphalerite, and relatively rare sodium chloride octahedron. We began to use the photoelectric properties of ZnO nanomaterials to explore its application in energy and environment, in order to achieve sustainable and coordinated development of energy and environment [7]. Due to the small particle size of nano ZnO. Moreover, the time for holes and electrons to reach the crystal surface from inside the crystal is shortened, reducing the probability of recombination of holes and electrons. Therefore, the antibacterial effect of nano ZnO is better than that of micron ZnO. Nano-ZnO has the advantages of low cost, easy crystallization and suitable band gap width. It has become an excellent photoanode material after TiO_2 , and its electron mobility is even higher than that of TiO_2 . In terms of energy, the goal is to achieve both open source and energy saving, and pay equal attention to energy and environmental protection. Firstly, we can use the luminescent properties of ZnO to develop economical and practical high-efficiency luminescent materials and long-life light-emitting diodes. Furthermore, a high-efficiency solid-state lighting device with good mechanical firmness and energy-saving and environmental protection was developed.

With the maturity of nano-scale ZnO preparation technology and the wider application fields, the research on ZnO defects has focused more on nano-structured ZnO materials. The smaller the original particle size of nano-ZnO, the stronger the ultraviolet absorption ability and the higher the transparency. There are many ways to grow or prepare ZnO, which can be divided into physical and chemical methods. Different growth methods have different characteristics, such as physical methods which are easier to control the structure, morphology and chemical composition of nanomaterials. At the same time, the purity of the obtained ZnO is higher and the crystal defects are less, and the chemical preparation method is usually simpler and easier than the physical method. Usually, the purity of ZnO crystal is low and there are many defects. Table 1 shows the properties of hexagonal wurtzite-type zinc oxide.

Table 1. Properties of hexagonal wurtzite ZnO

| Physical property | Numerical value |
|-----------------------------|------------------------|
| Density | 5.542g/cm ³ |
| Melting point | 1946°C |
| Thermal conductivity | 0.7, 1-1.5 |
| Static permittivity | 8.635 |
| Refractive index | 2.315, 2.674 |
| Band gap | 3.5eV, Direct jump |
| Exciton binding energy | 50meV |
| Effective mass of electrons | 0.25 |
| Hole effective mass | 0.61 |

Because of the large specific surface area of nano-ZnO, Zn^{2+} is easy to dissolve. Although Zn^{2+} can play an antibacterial role, the presence of a large amount of Zn^{2+} will increase the viscosity of the system and even result in gelation. If the system contains fatty acids and their salts, it will react with zinc ions to form zinc fatty acids. The larger the original particle size of nano-ZnO, the stronger the scattering ability of nano-ZnO to long-wave ultraviolet radiation. The maximum scattering ability of nano-ZnO for different wavelength ultraviolet light depends on its original particle size, secondary particle size and particle shape. In ZnO crystals, the atoms are packed in a hexagonal close [8]. The Zn atoms occupy half of the tetrahedral voids, and all the octahedral voids are empty. Therefore, there are a large number of sites to accommodate the intrinsic defects of ZnO or doped foreign ions. The preparation of one-

dimensional nano-ZnO by gas phase method requires a higher deposition zone temperature to obtain a product of high crystal quality. Therefore, it is unable to meet the needs of developing foldable and portable products in the future.

Increasing the specific surface area of ZnO porous electrodes and increasing the amount of dye adsorbed to absorb more photons are common methods to improve the efficiency of the battery. The efficiency of sensitized battery made of zinc oxide alone is not high. Improvement of ultraviolet shielding efficiency and visible light transparency of nano-ZnO has been the research direction of researchers. Nano-ZnO dispersion is a kind of slurry prepared by high shear mixing, ball milling or sand milling of nano-ZnO powder under the action of dispersant. When a porous electrode is prepared by a sol-gel method, a rapid heat treatment method can be employed to improve the crystallinity of the film and increase the porosity. And within a certain length range, the length of the ZnO nanowire array exhibits a positive correlation with battery performance. The nano-ZnO is difficult to disperse to the original particle size, and the transparency and ultraviolet shielding properties of the nano-ZnO cannot be fully exerted.

3. Application of Zinc Oxide Nanomaterials in Energy Resources

Nano-ZnO has a photocatalytic effect, and the radiation of ultraviolet rays generates a pair of hole electrons, and some holes and electrons migrate to the surface. The main direction in which ZnO materials still need further optimization is focused on changing the structure of nano-ZnO. In order to reduce surface defects of the photoanode film, the electron transport capability is improved. Controlling the defects of ZnO and its associated charge carriers play an important role in regulating the properties of ZnO-based materials. Previous studies on defects have focused on the performance and applications of ZnO varistors. Atomic oxygen and hydroxyl radicals are generated on the surface of the nano ZnO. These free radicals have strong ability of oxidation and reduction, and have adverse effects on skin cells. Defects and impurities in materials have very important effects on their properties. There are always some defects in ZnO, such as point defects, dislocations and grain boundaries. One-dimensional nano-ZnO was prepared by liquid phase method without any metal catalyst, and the final morphology and properties of the product could be effectively controlled by adjusting the process parameters.

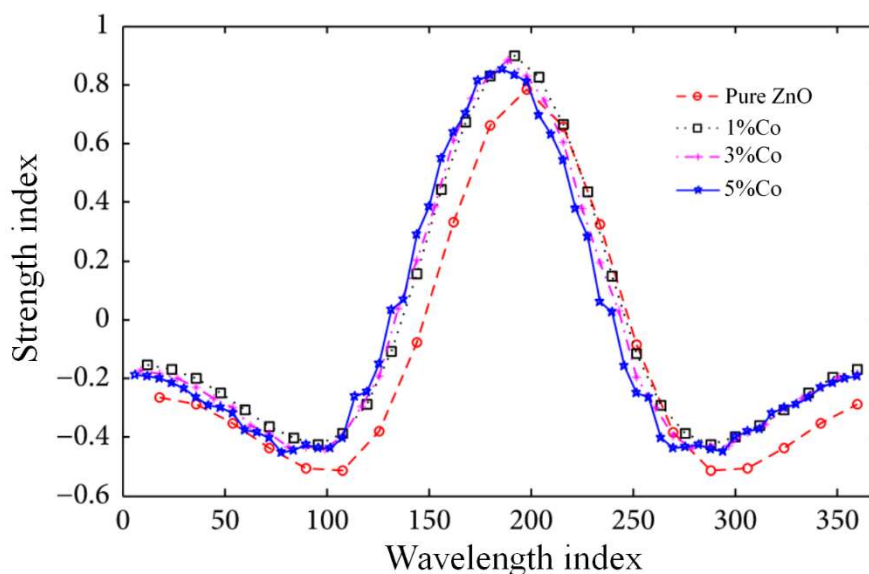
In view of the fact that nano-ZnO is easy to agglomerate, difficult to disperse, and has a poor feeling of use, sheet-like ZnO having a diameter of 0.1 μm to 1.0 μm , a thickness of 0.01 μm to 0.10 μm , and an aspect ratio of more than 3 is synthesized. The powder is easy to disperse, has a good feeling of adhesion to the skin, and has a good ultraviolet shielding effect. It is easy to use by users and can reduce the cost and improve the shielding ultraviolet effect of nano ZnO per unit mass. It also reduces dust pollution during the transport and use of nano-ZnO. At present, besides nanoparticles, there are also nanosheet electrodes and nanosheet spherical electrodes. In order to adapt to this situation, nano-ZnO was prepared into dispersions with good transparency and high UV shielding efficiency. When nanowire or nanotube arrays are used as electrodes, electrons will be directly derived from the contact between zinc oxide and the substrate, which can avoid electron scattering to a certain extent.

Surface defects and doping can obviously affect the intensity and location of the luminescence peak of ZnO. Indium doping can make the emission peak blue shift and enhance the green emission. However, when the amount of indium doping is high, the ultraviolet peak may be broadened and redshifted due to the increase of carrier concentration. After Sn doping, a large red shift of the UV peak was observed, and the defect luminescence peak was enhanced significantly. As shown in Table 2, the photoluminescence peaks and possible defect sources of ZnO at room temperature are shown.

Table 2. ZnO room temperature photoluminescence peak position and possible sources of defects

| Send peak / nm | Possible source of defects |
|----------------|------------------------------|
| 360-375 | Near-edge exciton reflection |
| -392 | Zinc vacancy |
| -416 | Surface defect vacancy |
| -431 | Oxygen vacancy |
| -450 | Copper magazine |
| -464 | O _{Zn} |
| -498 | Oxygen interstitial |

Figure 1 shows the fluorescence spectra of $\text{Zn}_{1-x}\text{Co}_x\text{O}$ nanopowders doped with different concentrations of Co^{2+} . As the Co^{2+} doping concentration increases, the fluorescence intensity gradually quenches. The doped Co^{2+} can be enriched at the grain boundary to form a localized state, which acts as an external quenching. As the Co^{2+} doping concentration increases, the crystal grains become smaller and the interface increases. Therefore, the non-radiative recombination process and the localized state at the interface will increase, resulting in the fluorescence emission intensity gradually decreasing with the increase of the concentration of Co^{2+} doped.

**Fig.1** Fluorescence spectra of $\text{Zn}_{1-x}\text{Co}_x\text{O}$ nanopowders doped with different concentrations of Co^{2+}

Compared with the gas phase method, the liquid phase method mainly refers to the preparation of one-dimensional nano-ZnO in the liquid phase state, and has the advantages of mild process conditions and convenient scale production. If the original particle size of the nano ZnO is too large, its ability to scatter visible light is correspondingly increased. ZnO has a high band gap at room temperature and is often used to make laser LEDs and luminescent LEDs. Moreover, it has a higher exciton binding energy than gallium nitride, which is also very high in band gap [9]. The surface of pure nano-ZnO or inorganic surface-treated nano-ZnO is hydrophilic and suitable for use in polar systems. In the visible region, many different luminescence peaks appear in the room temperature photoluminescence spectrum of ZnO [10]. Because the emission peaks are often broadened or overlapped, and the shape of the peaks is often asymmetric. Therefore, it is difficult to determine the corresponding specific defects. Compared with one-dimensional nano-ZnO prepared by gas phase method, the aspect ratio of one-dimensional nano-ZnO prepared by liquid phase method is often lower. At the same time, no matter which method is used in liquid phase method, the uniform orientation growth of one-dimensional nano-ZnO on the

specified region of the substrate surface can be achieved. In the later stage of the reaction, annealing treatment is often needed to improve the crystal quality of the product.

4. Conclusion

The research on the structure and photoelectric properties of ZnO nanomaterials largely determines whether they can be applied in energy and environment. Based on the current research results, it can be found that the specific surface area of the photoanode can be changed by adjusting the morphology of the ZnO nanostructure. In view of the fact that there are many defects on the surface of ZnO films and the serious charge recombination, some special nanostructures can be used to solve these problems. By changing the structure of ZnO nanomaterials and surface treatment, it is expected to achieve higher sensitizer load and smaller charge recombination. Based on the existing research, through more in-depth theoretical and experimental basic research. Then it guides its doping and compounding, and finally realizes its application in the fields of energy and environment. Photoanode materials with a higher specific surface area are more advantageous for the adsorption of sensitizers. It will further enhance the ability to capture sunlight, thereby improving the photoelectric conversion efficiency of the battery. These studies will certainly play a positive role in the research and development of related fields, especially nanotechnology.

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