



Synthesis of ZnO Nanoparticles by Using an Atmospheric-Pressure Plasma Jet

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Abstract

In this study, zinc oxide nanoparticles were synthesized by using an atmospheric-pressure plasma jet in NaOH-HNO₃ electrolytic system. Atmospheric-Pressure Plasma Jet was successfully used as the cathode and Zn sheet was used as the anode. The characterization of zinc oxide was obtained by X-ray powder diffraction (XRD), Fourier transformation infra-red (FTIR) and transmission electron microscope (TEM). The results show that the morphology of zinc oxide nanocrystals obtained by this technology is mainly dependent on the electrolytic media, current density and reaction temperature. The average grain size of ZnO nanoparticles is around 50.4 nm. These results encourage preparing these nanostructures for using in a great interest applications in solar cells, UV light emitting diodes, gas sensors, etc. This technique is low cost, scalable and general and should allow a wide range of nanoparticle materials to be synthesized in the gas or liquid phase.

Subject Areas

Plasma

Keywords

Zinc Oxide, Atmospheric Pressure Plasma Jet, Electrolytic System, Nanostructures

1. Introduction

In this study, a simple atmospheric plasma jet electrochemical technique is reported, where the plasma takes place at the gas-solution interface as the cathode for the synthesis of zinc oxide nanoparticles. Much interest was focused on exploring the effects of various process parameters such as the type of electrolyte, stirring, current density and temperature on the growth of zinc oxide nano-

structures. Moreover, the possible formation mechanism for the zinc oxide nanoparticles synthesized by the newest plasma-liquid electrochemical technology is discussed. Zinc oxide nanostructures have received a great interest due to potential applications in transparent electrodes, solar cells, blue/UV light emitting diodes, and sensors. [1] [2]. Stimulated by these applications significant attempts have been made in recent years to design ZnO-based composite nanostructures, such as doped and heterostructure nanocrystals. The composite nanostructures exhibit new optical and electronic properties due to the different functionality of their components. For example, the metal/semiconductor nanojunctions are being extensively studied for these purposes.

Up to now, ZnO nanostructures with various shapes have been synthesized by different methods including hydrothermal method, electrochemical route [3] [4] [5] [6] [7], chemical vapor deposition of precursors [8], solution synthesis method [9] and chemical method [10]. However, so far, no report has been researched on the synthesis of zinc oxide by atmospheric plasma-liquid electrochemistry technology. The atmospheric-pressure plasma jets have enormous interest from the plasma organization due to their characteristics of small physical size, excimer generation [11] [12] [13], atmospheric pressure stability [14] and non-equilibrium thermodynamics [15] [16]. These properties make atmospheric plasmas suitable for a wide range of applications, including medicine, gas treatment, textiles, surface modification and nanofabrication [17].

2. Experiment

Zinc oxide nanoparticles were synthesized by atmospheric plasma jet. A schematic diagram of the experimental set-up and a photograph of the discharge are shown in **Figure 1**. The system consists of a tube acted as the cathode made of stainless steel with 0.6 mm inner diameter and length is 7 cm, it was located 3 cm away from the zinc electrode. The zinc sheet acted as the anode (5 cm width, 10 cm length, immersion area is 2 cm²) with a gap of 3 mm between the tube end and the liquid surface. Argon gas flow was coupled to the tube and controlled by a glass flow meter at 60 ml/min. The action was occurred in glass basin, with width of 5.5 cm and length of 8.5 cm. The zinc anode was polished and washed with distilled water, and then immersed into electrolyte containing 1 g/L NaOH and 1.3 g/L HNO₃ and 1 g/L glucose (fructose) as stabilizers to prevent uncontrolled particle growth and agglomeration with the distilled water. The discharge was ignited by applying a high voltage of 3 kV with 40 KHz using AC power supply. The discharge current was kept constant in the range of 5 - 10 mA. The electrolyte was exposed at different time, (15, 30 and 45 min) and it can be observed the electrolyte systems shown in **Figure 2**. At the end of the synthesis, the sediments were centrifuged and washed with deionized water and ethanol for several times. Subsequently, the obtained products were dried at 60°C for 2 h.

3. Results and Discussion

Figure 3 shows the XRD patterns of the zinc oxide nanoparticles. It is no peak at

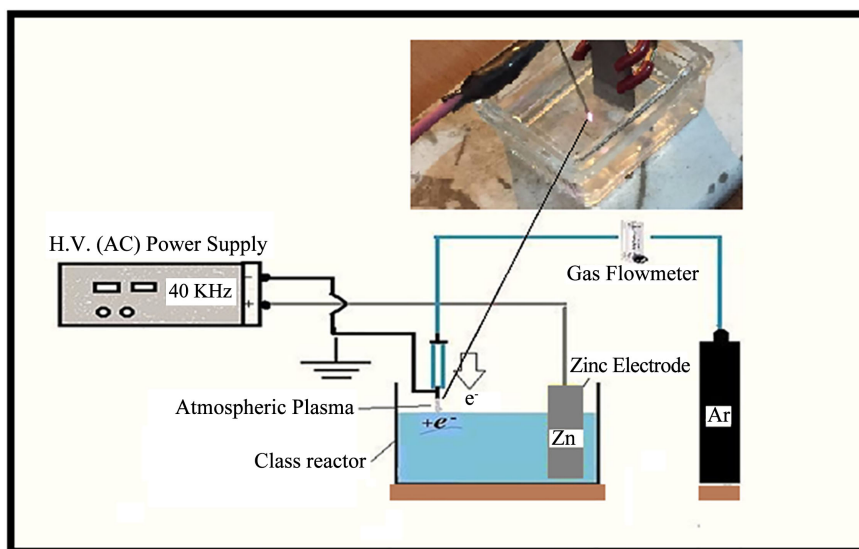


Figure 1. The schematic diagram of atmospheric plasma jet electrochemical synthesis of zinc oxide nanoparticles.

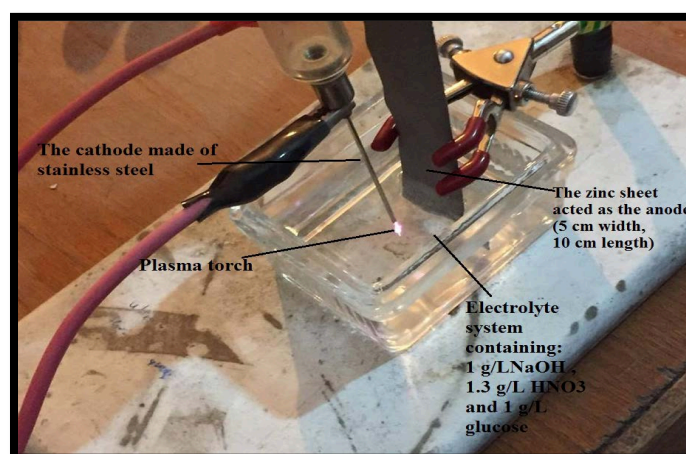


Figure 2. (Color online) at different discharge duration. The discharge current is 5 mA. The gap length is 3 mm.

preparation time 15 min as shown in **Figure 3(a)**, while when increasing preparation time 45 min it can be observe two peaks 34.45° and 38.1° , that are in well agreement with those for zinc oxide nanocrystals obtained from the International Center for Diffraction Data, USA (1979) JCPDS 1979, C 29-1133, (Joint Committee on Powder Standards) as shown in **Figure 3(b)**. This color of products could visually be seen from **Figure 4**. FTIR was used to estimate the chemical bonding configurations in the sediments zinc oxide nanoparticles. The recorded transmission spectra were in the range of $400 - 4000 \text{ cm}^{-1}$. **Figures 5**, shows that the peak observed at 3452.30 and 1119.15 cm^{-1} are may be due to O-H stretching and deformation, respectively assigned to the water adsorption on the metal surface. The peaks at 1634.00 , 620.93 cm^{-1} are belonging to Zn-O stretching and deformation vibration, respectively. The metal-oxygen frequencies

observed for the respective metal oxides are in accordance with literature values [18] [19]. V. Parthasarathi and G. Thilagavathi [20] reported similar FTIR spectra observed of zinc oxide nanoparticles in their investigation.

Transmission electron microscope for the prepared zinc oxide nanoparticles are shown in Figure 6. Dot shape ZnO nanoparticles were observed in TEM images of average size in the around 10 - 15 nm as shown in Figure 6(b) when the preparation time was increased and indicates that the particles are well crystallized.

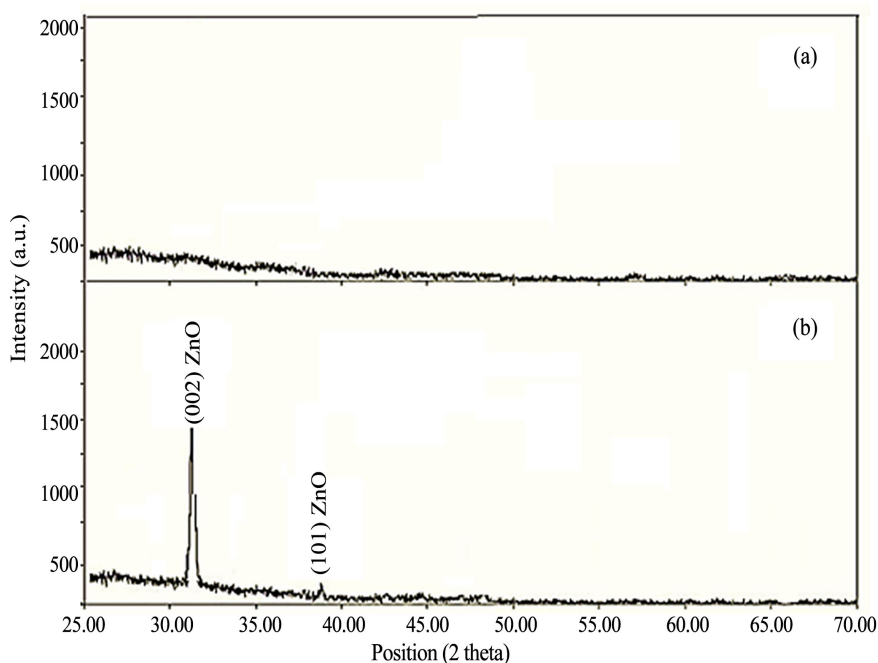


Figure 3. The XRD patterns of ZnO powder prepared by atmospheric pressure plasma jet electrochemical method in different compositions. (a) 15 min; (b) 45 min.



Figure 4. The pictures of ZnO powder (The sediment was centrifuged to investigate by XRD).

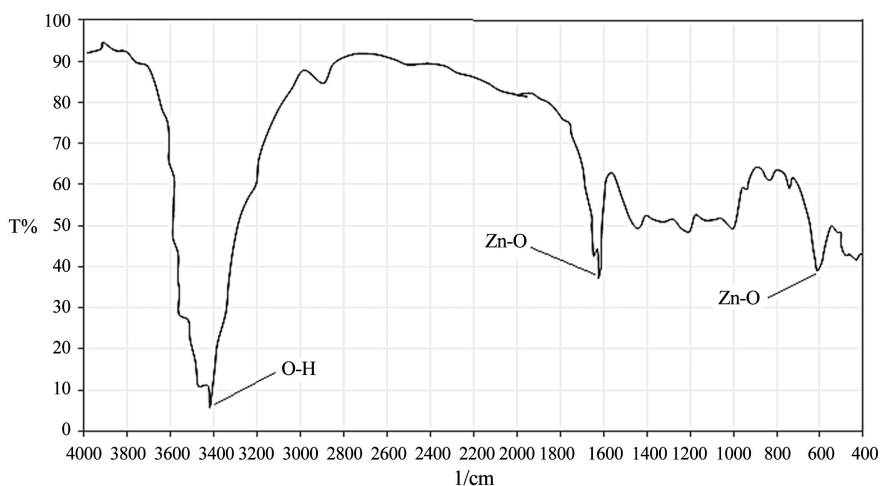


Figure 5. FTIR spectra of the zinc oxide nanostructures prepared in this work at 45 min preparation time.

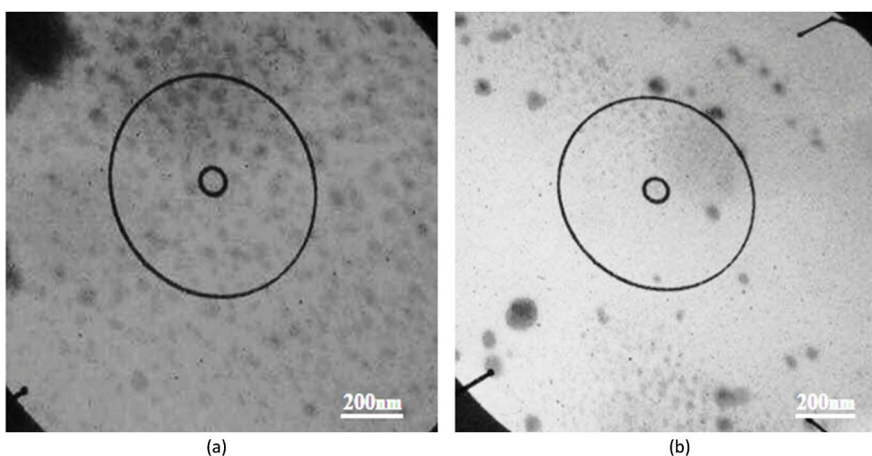


Figure 6. TEM images of ZnO nanoparticles prepared at preparation time (a) 15 min; (b) 45 min.

4. Conclusion

In this work, it was observed the capabilities atmospheric-pressure plasma jet to prepare zinc oxidenanometer-sized, uniform, high-purity in the gas or liquid phase. However, the theoretical fundamental of this method is new. Therefore, more efforts should be undertaken to demonstrate the present results to exploit this atmospheric-pressure plasma jet technology. The prepared zinc oxide nanoparticles have a widely application prospects in environmental governance. This result can be considered high and the work can be good attempt to prepare zinc oxide via atmospheric-pressure plasma jet as a new method and employ nanostructures in such important application.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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