Fabrication and characterization of zinc oxide nanoparticles by DC arc plasma

M. Zargar Shoushtari\textsuperscript{1,}, S. Parhoodeh\textsuperscript{1,2} and M. Farbod\textsuperscript{1}

1. Department of Physics, College of Science, Shahid Chamran University, 2. Physics department, Azad University of Shiraz

E-mail: m_zargar@scu.ac.ir, saeed.parhoodeh@scu.ac.ir, farbod_m@scu.ac.ir

Abstract. Zinc oxide nanoparticles were synthesized by DC arc plasma in pure oxygen atmosphere. High DC currents were passed through two approaching zinc rods in different oxygen pressures between 50 to 5000 mbars. Samples were characterized by TEM, SEM, XRD and electron diffraction analysis. The formation of zinc oxide nanoparticles were successfully proved by those analyses, although in some cases we had some unwanted materials. The XRD patterns show crystalline formation of zinc oxide, but in low pressures we have an excess peak belong to pure zinc. The height of this peak was reduced by increase in oxygen pressure and finally vanished completely at high pressure. The TEM and SEM images of samples show that in low pressures the samples mainly tend to have rod like shapes structures, but by increasing the oxygen pressure the structures steady revolve to the hexagonal nanocrystals. Upon the resulted data, the best conditions of arc plasma for desire product were inferred.

1. Introduction

Zinc oxide is a material with wide application in different industries. The unique properties of ZnO plus low cost and non toxicity make it suitable for many purposes. This well known semiconductor has wide band gap (3.37 eV) and high excitation binding energy of 60 meV at room temperature [1]. Although zinc oxide has been widely used in nowadays pressure - gas sensors, solar cells, UV light emitting – detecting devices, medicine, catalyst and many other devices and applications [2], but the study and research to improve the efficiency of such devices and materials has been continued until now. Fabrication of zinc oxide nanoparticles is one of such efforts which were widely attracted attentions in order to use the benefits of increase in effective surface in result of decreasing particle size.

Here we have used and developed a simple, one step procedure to fabricate zinc oxide nanoparticles. The procedure has the advantages of high purity of resulted product which is lack in almost customary chemical processes.

2. Method principle

The procedure is based on simultaneous evaporation and ionization of pure metal in presence of a carrier gas which has the role of charge transferer and also is a component of our final compound.

\textsuperscript{*} Corresponding author: Tel: +98 916 618 0447; Fax: +98 611 333 1040, Blvd. Golstan, Shahid Chamran University, Faculty of science, Physics department, Ahvaz, I. R. Iran.
Figure 1. XRD patterns of samples which were produced in different pressures. (a) 50 mbar, (b) 550 mbar, (c) 850 mbar, (d) 3000 mbar, (e) 5000 mbar. As shown in the figure, the peak which belongs to (101) of zinc has reduced by increasing of the pressure.

In other words we have tried to generate simultaneously a mixture of metal plasma and carrier gas to produce nanoparticles of our desire product.

The critical points in formation, particle size and morphology of resulted nanoparticles are the conditions which define plasma stability, formation time (the effective presence time of particles in plasma) and the rate at which the output particles (particles which exit from the effective plasma volume) lose their energy and temperature. However there are secondary parameters such as plasma temperature, plasma effective volume (the effective volume in which the plasma has formed), chamber volume and chamber walls temperatures which can affect the first ones.

We have tried to reach above procedure to fabricate nanoparticles by passing high current throw, two approaching pure rods of a metal (zinc) in presence of an oxidant gas (oxygen).

3. Experimental Procedure
Zinc oxide nanoparticles were fabricated by passing high current through two approaching pure zinc rods in oxygen atmosphere. In order to prepare pure atmosphere of oxygen, we have used cylindrical chamber with approximate volume of 7000 cm$^3$. The chamber was evacuated down to $10^{-7}$ mbar by means of a rotary pump and then it was filled with pure oxygen up to 1.5 bar. The procedure was repeated three times to insure the purity of atmosphere. At final we were using rotary pump for fourth time to set atmosphere pressure at desired value.

Two pure zinc rods with approximately 6 mm diameter were placed in chamber before above procedure. The rods were connected to high DC source of current. The supply was adjusted to allow passing maximum current of 250A. One of the rods was fixed at center of the chamber and the second
one develops toward it by means of a controllable DC motor. As soon as two rods approach to each other enough, a white-blue arc started. The arc was maintained for three minutes.

The above procedure was performed for different pressures of 50, 200, 350, 550, 850, 1050, 1250, 1400, 3000 and 5000 mbars. Less than 50 mbar pressures a stable arc could not be maintain with such currents.

The produced zinc oxide nanoparticles were analyzed by means of x-ray diffraction, scanning electron microscope and transition electron microscope.

4. Results and Discussion

4.1. XRD
X-ray diffraction of samples was measured by use of a Philips 1840 x-ray diffractometer. The XRD patterns show the high quality synthesized ZnO nanoparticles which had hexagonal structures. At low pressures we observed an excess peak which was the (101) peak of pure zinc (figure 1). The height of this excess peak reduces regularly by increase in atmosphere pressure and finally vanishes completely above 5000 mbar of oxygen pressure which means that we have no more pure zinc in the samples (figure 1).

4.2. SEM and TEM
Scanning electron microscope and transmission electron microscope images of samples were captured. At low pressures as viewed in figure 2, there are zinc oxide nanoparticles with different morphology, but as the pressure increases the shape of samples become completely smooth and homogenous toward round spherical shapes (figure 2).

Figure 2. TEM images of samples which were produced at pressures of (a) 50 mbar, (b) 850 mbar, and SEM images of samples which were produced at pressures of (c) 1050 mbar, (d) 3000 mbar.
5. Conclusion
We have synthesized zinc oxide nanoparticles by DC arc plasma in oxygen atmosphere. XRD patterns show that; in order to have pure spherical zinc oxide nanoparticles, it is convenient to do above procedure at high pressure.

SEM and TEM images of samples shows that as if we want different morphology of zinc oxide nanoparticles, we can use the lower pressures, although more investigation and research should be done in order to reach more homogenous samples.

Acknowledgement
This research was financially supported by Shahid Chamran University.

References
[1] Z.K. Tang, G.K.L.Wong, P. Yu, M. Kawasaki, A. Ohotomo, H. Koimuma, Y. Segawa, Appl. Phys. Lett. 72 (1998) 3270.
[2] E.M. Wong, P.C. Searson, Appl. Phys. Lett. 74 (1999) 2939.