

## Preparation of Zinc Oxide Nanostructures by Thermal Oxidation of Zinc:Zinc Oxide:Carbon Mixtures

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### ABSTRACT

*Zinc oxide nanostructures were prepared by thermal oxidation of zinc, zinc oxide and carbon mixtures. The mixture was screened on the alumina substrate and heated at 800°C for 1 hour under normal atmosphere. The influence of the mixture ratio on the formation of nanostructure was investigated with field emission scanning electron microscope and an energy dispersive spectroscope. It was found that the size of nanostructures depended on the ratio of the mixture. The higher ZnO:Zn ratio led to the formation of shorter, and less density of nanostructure. However, there was a number ratios with carbon that could form long and high density of nanostructure.*

**Key words:** Zinc oxide, Nanostructure, Nanowire, Nanobelt

### INTRODUCTION

Zinc oxide is a metal oxide wide-band gap semiconductor (Christoulakis et al., 2006) which has been widely studied. These include the fabrication of nanodevices (Wang et al., 2006) and various applications, such as gas sensors (Nanto et al., 1996), piezoelectric devices (Gardeniers et al., 1998), varistors (Miguel et al., 2006), planar optical waveguides (Wenas et al., 1991), transparent electrodes (Kim et al., 1997), ultraviolet photodetectors, surface acoustic wave devices. Zinc oxide nanostructures could be synthesized by several techniques such as vapor deposition, sputtering, pulsed laser deposition (PLD), oxidation and screen printing (silk screen). Screen printing has been developed in the fields of microelectronics for hybrid and integrated circuit manufactures (Miguel et al., 2006) and this technique is well known as one of most important thick film deposition methods (Ivanov, 2004). The advantages of this method are simple, low cost, fast and high reproducibility.

In this work, zinc oxide nanostructures were synthesized by thermal oxidation using screen printing of zinc, zinc oxide and carbon mixtures. The effect of the mixture ratio on the formation of nanostructures was investigated.

## MATERIALS AND METHODS

Zinc oxide nanostructures were prepared by thermal oxidation technique. The starting materials, zinc (Zn), zinc oxide (ZnO) and carbon (C) powders were mixed in the various ratio by molar of Zn: ZnO: C with 1:0:0, 2:1:0, 1:1:0, 1:2:0, 2:0:1, 1:0:1, 1:0:2, 4:2:3, 4:2:2 and 4:3:2. The mixed powders were hand-grounded in agate mortar with polyvinyl alcohol (PVA). After that, the mixture was screened on alumina substrate and heated under atmosphere at 800°C for 1 hour. Zinc oxide nanostructures were characterized by Field-Emission Scanning Electron Microscopy (FE-SEM) for morphology and energy dispersive spectroscopy (EDS) for chemical composition. From SEM images, we used computer program (Image J) to carry out density of nanostructures by fixed area of 25  $\mu\text{m}^2$  (number of nanostructure/25  $\mu\text{m}^2$ ) for 5 times per condition, then the average value of density of nanostructures were obtained.

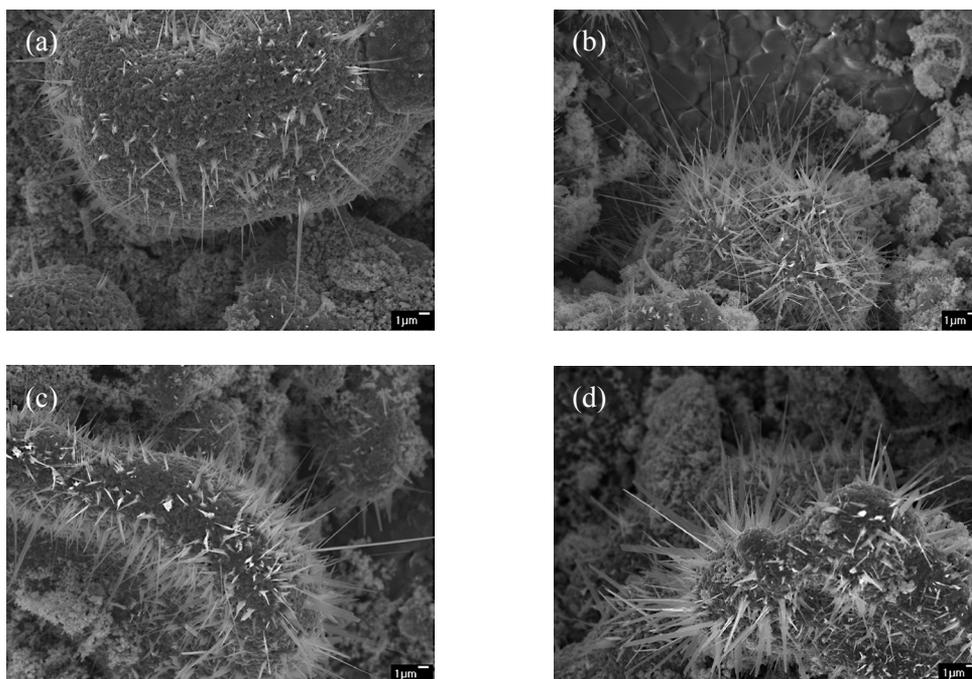
## RESULTS AND DISCUSSION

Before heating, the color of starting materials are gray and black depending on the amount of zinc and carbon powders since typical color of zinc and carbon are black respectively. After heating, zinc was oxidized with oxygen in normal atmosphere and transformed to zinc oxide and thus, the color of thick films changed from black or gray to yellow or white which is the typical color of zinc oxide. The morphology of zinc oxide nanostructures grown on alumina substrates at various Zn: ZnO: C ratio was shown in Figure 1. The wire-like nanostructures were observed only at the ratio of 1:0:1 (Figure 1(b)). For the other ratios, the belt-like nanostructures were observed.

**Table 1.** The color of ZnO nanostructures before and after heating.

Type of films	Color before heating	Color after heating
Zn : ZnO	gray	yellow + white
Zn : C	black	yellow + white
Zn : ZnO : C	black	yellow + white

The colors of ZnO nanostructures were toned to change after heating under atmosphere at 800°C for 1 hour as listed in Table 1.



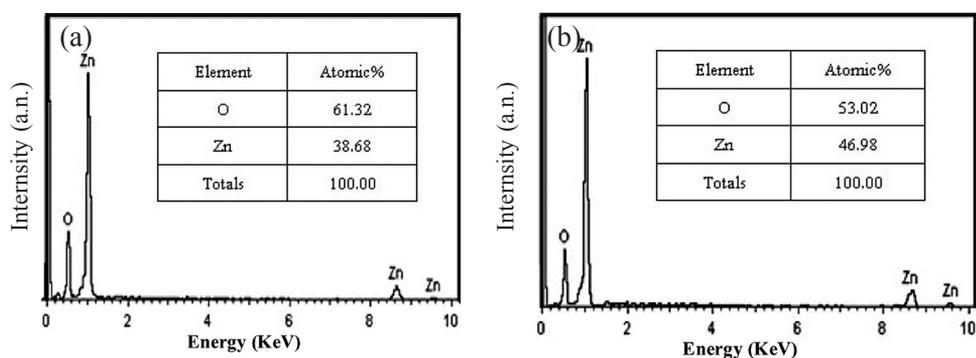
**Figure 1.** FE-SEM images of thick films with various Zn: ZnO: C ratio of (a) 2: 1:0, (b) 1:0:1, (c) 4:2:3, (d) 4:2:2.

The length and density of zinc oxide nanostructures at different ratios were shown in Table 2. The length and density of zinc oxide nanostructures depended on the Zn: ZnO: C ratio. The higher ZnO:Zn ratio led to the formation of shorter, and less density of nanostructures. However, there was a number ratios with carbon that could form long and high density of zinc oxide nanostructures.

**Table 2.** The length and density of zinc oxide nanostructures at different Zn: ZnO: C ratio.

Zn: ZnO: C ratio	Type of ZnO nanostructure	Average length ( $\mu\text{m}$ )	Density (number of nanostructures/ $25\mu\text{m}^2$ )
1:0:0	Belt	2.96	6
2:1:0	Belt	5.16	20
1:1:0	Belt	2.23	8
1:2:0	Belt	1.90	5
2:0:1	Belt	4.85	9
1:0:1	Wire	20.73	18
1:0:2	Belt	4.64	15
4:2:3	Belt	4.84	9
4:2:2	Belt	6.92	20
4:3:2	Belt	6.24	8

Figure 2 showed EDS spectra of (a) zinc oxide nanowire and (b) zinc oxide nanobelt. The spectra were obtained by focusing electron beam in a middle of nanostructures. The peaks at Zn and O signals were observed indicating Zn was oxidized with O and formed zinc oxide nanostructures. The atomic ratio of zinc and oxygen from the EDS spectra of nanowire and nanobelt were 39:61 and 47:53, respectively, which was nearly 1:1 ratio. Thus, the obtained nanostructures could be considered as ZnO.



**Figure 2.** EDS spectra of (a) ZnO nanowires and (b) ZnO nanobelts.

## CONCLUSION

The zinc oxide nanostructures were successfully synthesized by thermal oxidation of zinc, zinc oxide and carbon mixture with various Zn: ZnO: C ratios. From FE-SEM analysis, it was found that the size of nanostructures depended on the ratio of the mixture. The higher ZnO:Zn ratio led to the formation of shorter, and less density of nanostructure. However, there was a number ratios with carbon that could form long and high density of nanostructure.

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