

Research Article

Influence of OH^- Ion Concentration on the Surface Morphology of ZnO-SiO_2 Nanostructure

Jessica Ven G. Tinio, Key T. Simfroso, Amber Dea Marie V. Peguit, and Rolando T. Candidato Jr.

Materials Science Laboratory, Physics Department, College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, A. Bonifacio Avenue, Tibanga, 9200 Iligan, Philippines

Correspondence should be addressed to Rolando T. Candidato Jr.; r.candidatojr@gmail.com

Received 23 July 2015; Revised 2 September 2015; Accepted 3 September 2015

Academic Editor: Yuxin Zhao

Copyright © 2015 Jessica Ven G. Tinio et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The influence of varying OH^- ion concentration on the surface morphology of chemically deposited ZnO-SiO_2 nanostructures on glass substrate was investigated. The morphological features, phase structure, and infrared characteristics were examined by scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR), respectively. Results revealed that silica significantly changes the hexagonal morphology of bare ZnO rod to “pointed tips” when using low initial OH^- precursor concentration. Increasing OH^- ion concentration resulted in a “flower-like” formation of ZnO-SiO_2 and a remarkable change from “pointed tips” to “hemispherical tips” at the top surface of the rods. The surface capping of SiO_2 to ZnO leads to the formation of these “hemispherical tips.” The infrared spectroscopic analysis showed the characteristics peaks of ZnO and SiO_2 as well as the Si-O-Zn band which confirms the formation of ZnO-SiO_2 . Phase analysis manifested that the formed ZnO-SiO_2 is of wurtzite structure. Furthermore, a possible growth mechanism is proposed based on the obtained results.

1. Introduction

Zinc oxide (ZnO) is a widely known *n*-type semiconductor that attracted research interest due to its properties like wide energy band gap of 3.37 eV and high exciton binding energy of 60 meV [1] which makes it suitable for many applications like in solar cells [2], photodetectors [3], and gas sensors [4]. Another interesting aspect of ZnO growth is its ability to be engineered to different structural features by changing some parameters during synthesis. Tailoring the morphology, shape, and size of ZnO could be a way of expanding its potential especially in solar cell and sensor technologies where reaction at the surface is very crucial. Works have been reported for controlling size and shape of ZnO nanostructures like varying the initial zinc and hydroxyl ion concentrations [5, 6] and also by introducing silica (SiO_2) to ZnO as a concept of composite material [7, 8]. With good mechanical resistance and high dielectric strength, SiO_2 is likely to be an ideal component to enhance the properties of ZnO. ZnO-SiO_2 is seen to have significant

potential application as an antibacterial coating [9], luminescent material [10, 11], photocatalyst [12], and also as gas sensor [13] because of the good sensing capability of ZnO which could be enhanced more with the presence of SiO_2 for size and shape control that could lead to better chemical activity at the surface. However, understanding the mechanism for the growth of ZnO-SiO_2 nanostructures is still a formidable task particularly on controlling its surface morphology. Aside from these, most works related to ZnO synthesis use complex processes and sophisticated equipment like PLD [14], CVD [15, 16], and vapor phase transport process [17–19] among others which is not practical and economical in nature.

Recently, we reported preliminary investigations on the synthesis of ZnO-SiO_2 both in powder form [20] and deposited on glass substrates [21] by using simple wet chemical deposition process. It is also worth mentioning that the SiO_2 from rice husk ash, a naturally occurring material, was used as an alternative to the expensive liquid tetraethyl orthosilicate (TEOS). We found out that SiO_2 modifies the surface of ZnO from hexagonal into pointed tips

TABLE 1: List of parameters of solution used for ZnO-SiO₂ synthesis.

Sample	ZnSO ₄ concentration	NH ₄ OH concentration	SiO ₂
1	0.03 M	1.0 M	0.1 grams
2	0.03 M	2.0 M	0.1 grams
3	0.03 M	3.0 M	0.1 grams

and confirms the attachment of SiO₂ to ZnO through FTIR spectroscopy. In this current contribution, the influence of initial OH⁻ ion concentration on the surface morphology of ZnO-SiO₂ is presented. Moreover, a proposed mechanism for the growth of ZnO-SiO₂ on glass substrates is also presented based on the evolution of morphology of ZnO-SiO₂ with varying initial OH⁻ ion concentration. Results of this work would pave the way for the control of the morphology of the nanostructures and for its possible use as methane gas detector.

2. Experimental Procedure

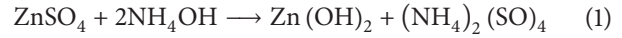
2.1. Wet Chemical Deposition Process. ZnO-SiO₂ nanostructures were synthesized through low temperature chemical deposition process using zinc sulphate (ZnSO₄) and ammonium hydroxide (NH₄OH). First, 0.03 M ZnSO₄ aqueous solution and varied ammonium hydroxide (NH₄OH) concentrations (1.0 M, 2.0 M, and 3.0 M) were prepared separately in a beaker. The ammonium hydroxide was then added dropwise to the ZnSO₄ solution and magnetically stirred while subsequently placing the precleaned glass substrates. After 30 minutes' stirring of the mixed precursors, 0.1 grams of laboratory (in-house) prepared amorphous silica powder was then added and then the solution was continuously stirred for 3 hours while maintaining the bath temperature at 70°C. After 3 hours of constant stirring and heating, the substrates were washed with distilled water in order to remove loosely attached residues present and were allowed to dry at ambient room temperature. Table 1 shows the parameters considered for the synthesis of ZnO-SiO₂ where fixed concentration of ZnSO₄ was used at varying NH₄OH concentrations. The amount of amorphous silica powder used was the same for all samples.

2.2. Characterization of Materials. The morphological characteristics of the samples were studied using JEOL JSM-6510LA analytical scanning electron microscope at low and high magnifications. Functional groups were determined by using Perkin Elmer Spectrum 100 infrared spectrometer from 4000 to 650 cm⁻¹ over 32 scans with 4 cm⁻¹ spectral resolution. Phase analysis of the samples was studied by X-ray diffraction analysis using Shimadzu XRD-7000 diffractometer from 5 to 40° (2θ) with step scanning mode of 0.02° (2θ).

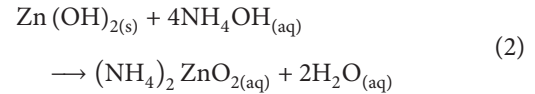
3. Chemistry of Precursors for the Synthesis of ZnO-SiO₂

To understand the mechanism for the deposition of ZnO-SiO₂, it is better to look first on the growth of ZnO prior

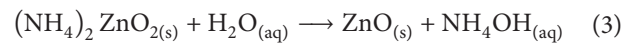
to addition of SiO₂. The reaction between zinc sulfate and ammonium hydroxide upon dissociation in aqueous solution results in the formation of Zn(OH)₂ which acts as seed nuclei for the growth of ZnO. The reaction is expressed in



The formation of Zn(OH)₂ induces rapid nucleation and further addition of ammonia dissolves the solid Zn(OH)₂ to form ammonium-zincate bath shown in



On further reaction with water in the active solution during deposition, ZnO forms according to this chemical reaction:



Upon addition of SiO₂ to the solution, the silica particles in the solution might interact with the OH⁻ group of Zn(OH)₂ because the surface of silica is composed of functional groups, namely, siloxane (Si-O-Si) bridges and silanol groups (Si-OH) where the OH⁻ group acts as the center of molecular adsorption. Thus, a competition of attraction to OH-group of the Zn(OH)₂ seed nuclei between silica and the formation of ZnO is possible to happen.

4. Results and Discussions

4.1. Characteristics of ZnO-SiO₂ Using 1.0 M NH₄OH. To show that indeed ZnO-SiO₂ can be synthesized using silica from rice husk ash via chemical deposition process, a figure of bare ZnO is presented first to have an idea on what would be the effect of SiO₂ on ZnO. Figure 1(a) presents a typical micrograph of ZnO grown on glass substrate. It was observed that dense and well-defined hexagonal nanorods were present and preferentially grow perpendicular to the glass substrate, though some were tilted. The hexagonal feature of the micrograph is a characteristic of a wurtzite structure which is the more stable phase of synthetic ZnO. Figure 1(b) meanwhile shows the corresponding IR spectra of bare ZnO. The peaks observed at 779 cm⁻¹ and 3279 cm⁻¹ are attributed to the stretching mode and hydroxyl group of ZnO, respectively [22]. On the other hand, Figure 2 shows the micrograph of amorphous SiO₂ and its FTIR data. It can be seen in Figure 2(a) that the SiO₂ particles were agglomerated and were found to have micron size (>3 μm). Additionally, Figure 2(b) presents the characteristic infrared spectra of amorphous SiO₂. Peak observed at 474 cm⁻¹ is for the bending vibration of Si-O-Si bond while 804 and 1098 cm⁻¹ are the vibrational bonds of Si-O. The peak at 3470 cm⁻¹ is for both the Si-OH and the O-H vibration of physically adsorbed water [23].

Figure 3 on the other hand shows the micrographs using the same concentration of precursors as in Figure 1 but added with amorphous SiO₂ powder grown also on glass substrates. It can be observed that the micrographs have uniform growth of dense ZnO rods. The surface morphology

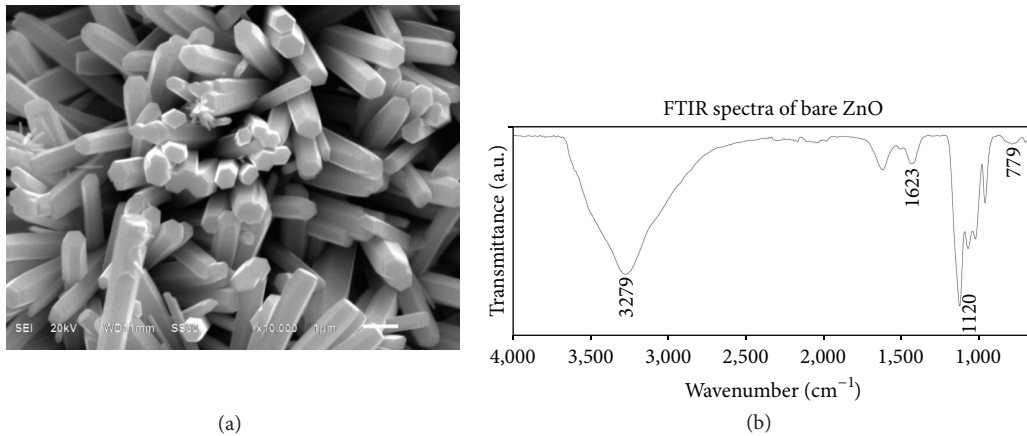


FIGURE 1: (a) SEM image of as-grown bare ZnO on glass substrate using 0.03 M ZnSO₄ and 1.0 M NH₄OH showing hexagonal rods and (b) corresponding FTIR spectra.

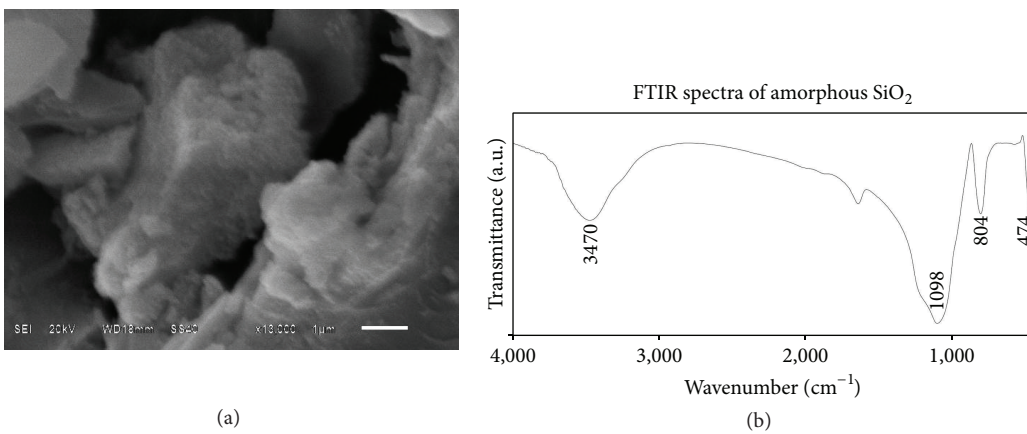


FIGURE 2: (a) SEM image of amorphous silica and (b) its corresponding FTIR spectra peaks.

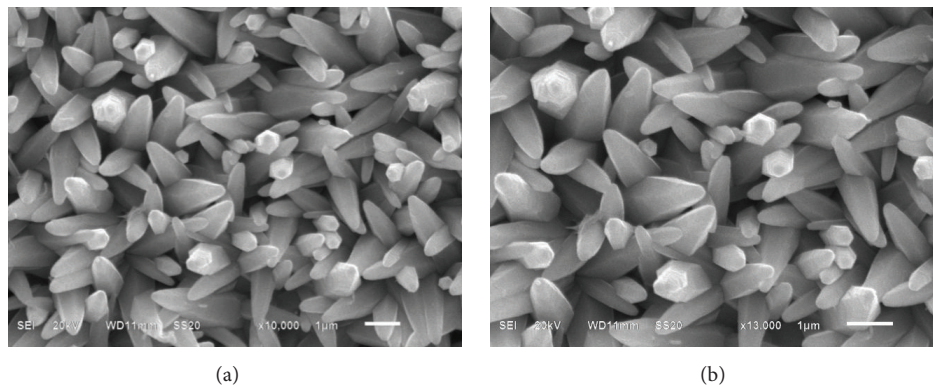


FIGURE 3: Micrographs of as-grown ZnO-SiO₂ on glass substrate using 1.0 M NH₄OH. At (a) 10,000x magnification and (b) 13,000x magnification.

shows the preferential growth at *c*-axis having pointed tips of approximately 250 nm in average diameter and 2 µm in average length which is far different compared to the morphology of bare ZnO. The modification at the surface of ZnO from hexagonal to pointed tips is due to the presence of SiO₂ where it attaches to the nonpolar facets of ZnO which

hinders the formation of hexagonal structure at its metastable facet. To maintain a much stable structure, the polar facets of ZnO may undergo surface reconstruction during the chemical deposition process resulting in the pointed tips of ZnO rods. Using low OH⁻ ion concentration enables the growth of the mostly *c*-axis oriented ZnO-SiO₂ rods. This

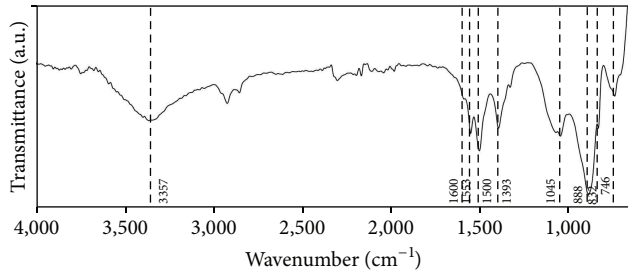


FIGURE 4: FTIR spectra of ZnO-SiO₂ using 1.0 M NH₄OH showing the functional groups of silica and ZnO.

growth habit is due to the higher growth rate along the (0001) plane compared to other growth faces of ZnO.

To confirm ZnO-SiO₂ formation, the infrared spectrum of ZnO-SiO₂ using 1.0 M NH₄OH is shown in Figure 4. Characteristic peak at 746 cm⁻¹ indicates the presence of ZnO [22]. The peaks at 832 cm⁻¹ and 888 cm⁻¹ are for the Si-O-Si asymmetric stretching vibrations while peak at 1063 cm⁻¹ is for the Si-O-Si symmetric stretching. Peaks observed at 1500 cm⁻¹ and 1553 cm⁻¹ are for the Si-OH stretching vibration and the peak at 1393 cm⁻¹ is for the Si-O-Si bending. All of these characteristic peaks indicate the presence of the functional groups of amorphous silica from RHA. Furthermore, peak at 1600 cm⁻¹ and a broad absorption band situated at 3000 cm⁻¹ to 3600 cm⁻¹ are attributed to the O-H bending and O-H stretching vibrations of ZnO-SiO₂, respectively, which reveals the presence of physically adsorbed water. Moreover, the peak at 1045 cm⁻¹ is assigned for the Si-O-Zn stretching which confirms the formation of ZnO-SiO₂ [24, 25].

4.2. Characteristics of ZnO-SiO₂ Using Higher NH₄OH Concentration. Increasing the ammonium hydroxide concentration resulted into much larger diameter but shorter rods. Flower-like formation and apparent change from pointed tips to hemispherical tips on the surface of the structures were observed as shown in Figure 5 for ZnO-SiO₂ deposited on glass substrate using 2.0 M NH₄OH. On the other hand, Figure 6 shows the micrographs of ZnO-SiO₂ using 3.0 M NH₄OH where much shorter (~0.850 μm) rods were present together with flake-like structures. The formation of flower-like structures using high NH₄OH concentration was due to the sufficient amount of OH⁻ which was necessary for the nucleation and subsequently growth of anisotropic ZnO-SiO₂. The amorphous silica added to the ammonium-zincate bath solution causes the formation of hemispherical tips of the flower-like structures and is also the reason for having shorter and thicker rods. It is believed that, in higher OH⁻ ion concentration, the SiO₂ capped the surface of ZnO rods leading to the formation of these hemispherical tips. This is due to enough OH⁻ ions that interact with the silanol group of silica in the solution. The notable flakes observed in Figure 6 (encircled) are associated with the excess OH⁻ ions and may form Zn complexes.

Figure 7 shows the infrared spectra of the chemically deposited ZnO-SiO₂ nanostructures prepared using high

OH⁻ ion concentration together with the spectra of ZnO-SiO₂ prepared using 1.0 M NH₄OH for comparison. It was observed that intensity of the peaks at 1500 cm⁻¹ and 1553 cm⁻¹ attributed to the Si-OH (silanol) stretches of silica decreases while peak at 1045–1050 associated with the Si-O-Zn band has a more pronounced intensity as OH⁻ ion concentration is increased. This observation might suggest that the silanol group interacts with the OH⁻ ions in the solution and that prolonged stirring resulted in the surface capping of SiO₂ to ZnO resulting in the formation of flower-like ZnO-SiO₂ with hemispherical tips.

The X-ray diffraction diagram of the bare ZnO and amorphous SiO₂ and the chemically deposited ZnO-SiO₂ nanostructures at varying OH⁻ ion concentration are presented in Figures 8 and 9, respectively. A broad peak is observed centered at 21.6° (2θ) which is attributed to the amorphous nature of SiO₂ [26] while the diffractogram of bare ZnO showed the (100), (002), and (101) reflections indicating the formation of ZnO. Presence of sulfides and hydroxides of zinc was also observed which is due to the precursors used as depicted in Figure 8. Figure 9, on the other hand, shows the diffractogram of the prepared ZnO-SiO₂ samples. Phase analysis revealed that the peaks correspond to wurtzite structure of ZnO as indexed to PDF 36-1451. The broad hump observed at 15–30° (2θ) was associated to the amorphous silica added in the ammonium-zincate bath for the synthesis of ZnO-SiO₂; the same diffractogram was observed as in the work of [27]. Presence of hydroxide of zinc was also observed.

4.3. Proposed Mechanism for the Growth of ZnO-SiO₂. Following the chemistry of solution as previously discussed, the dropwise addition of NH₄OH to aqueous solution of ZnSO₄ produces Zn(OH)₂ precipitate. For ZnO-SiO₂ prepared using 1.0 M NH₄OH, the Zn(OH)₂ produces Zn²⁺ and OH⁻ ions upon dissociation and induces the formation of ZnO nuclei. Based on the growth habit of ZnO, using low initial OH⁻ ion concentration (1.0 M) resulted in a slow rate of ZnO nuclei formation leading to the creation of flat end-rods with hexagonal shape as observed in Figure 1. This can be explained by the high growth rate along the (0001) plane of ZnO compared to the other growth faces resulting in a rod-like structure. Upon addition of amorphous silica to the solution, the silanol functional group of silica attaches to the nonpolar facets of ZnO and, to maintain a stable structure, the metastable polar facet of ZnO exhibits surface reconstruction resulting in the pointed tips of ZnO-SiO₂ rods.

However, using high initial OH⁻ ion concentrations (2.0 M and 3.0 M) resulted in the flower-like formation of ZnO-SiO₂ with hemispherical tips. Based on the micrographs, hydroxide cluster formation might be favourable for the growth of flower-like structures. Since there are sufficient OH⁻ ions, more Zn(OH)₂ clusters were formed and subsequently adhere on the glass substrates which serve as seed nuclei while some may dissociate to Zn²⁺ and OH⁻ ions. Further addition of NH₄OH triggers more formation of Zn(OH)₂ which tends to continuously produce free Zn²⁺ and OH⁻ ions and starts to form ZnO rods on the Zn(OH)₂

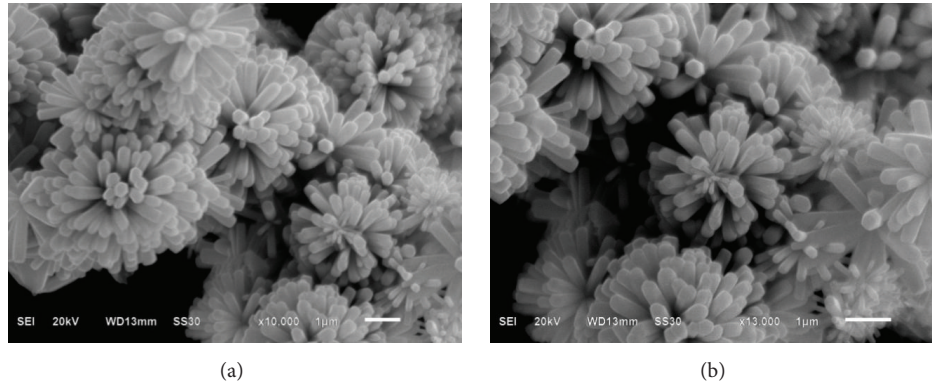


FIGURE 5: Micrograph of ZnO-SiO₂ using 2.0 M NH₄OH showing flower-like ZnO-SiO₂ nanostructures having hemispherical tips. At (a) 10,000x magnification and (b) 13,000x magnification.

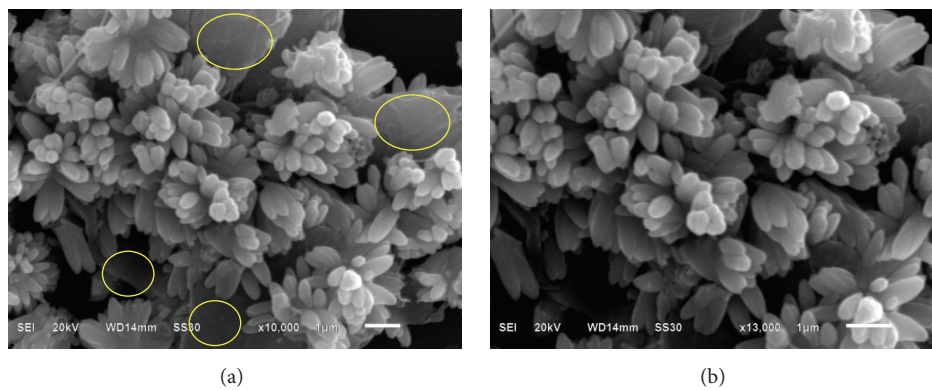


FIGURE 6: Micrograph of ZnO-SiO₂ using 3.0 M NH₄OH showing flower-like ZnO-SiO₂ nanostructures having shorter rods and more pronounced hemispherical tips. At (a) 10,000x magnification and (b) 13,000x magnification. Encircled are the flake-like structures.

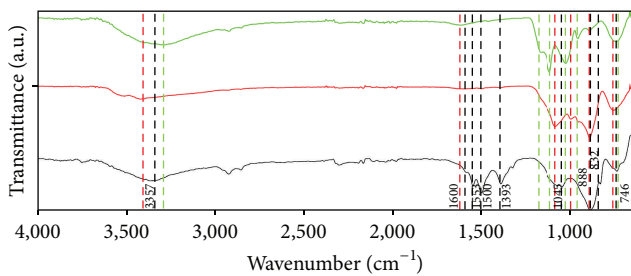


FIGURE 7: Infrared spectra of the as-grown ZnO-SiO₂ on glass substrate using 1.0 M (black), 2.0 M (red), and 3.0 M (green) NH₄OH.

seed nuclei. When amorphous silica was added, its silanol group attaches to the free OH⁻ ions competing against the Zn²⁺ ions leaving more Zn²⁺ resulting in the formation of thicker and shorter ZnO-SiO₂ rods. Excess OH⁻ ions, especially using 3.0 M NH₄OH, lead to the formation of zinc complexes as evidently suggested by the flake-like structures. As deposition time is prolonged, ZnO-SiO₂ structures were slowly deposited on the substrate having already seed nuclei and, consequently, the neighbouring ZnO from the solution adheres on the seed nuclei that were already deposited on the

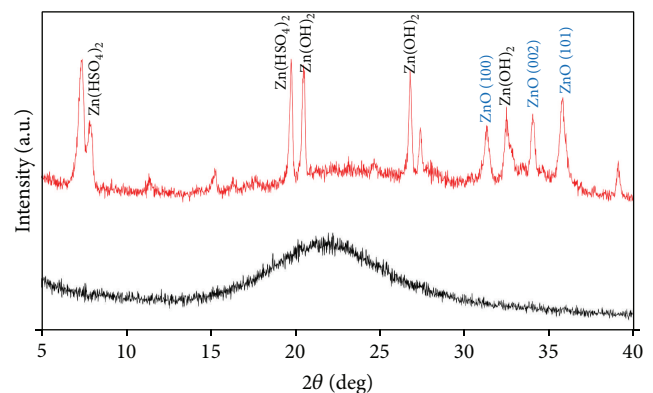


FIGURE 8: X-ray diffraction plot of amorphous SiO₂ used in the study.

substrate and forms the flower-like structure. The formation of hemispherical tips is believed to be due to enough OH⁻ ions present in the solution that attaches to the silanol group (Si-OH) of silica and then subsequently caps the surface of ZnO rods resulting also in a much bigger but shorter rod.

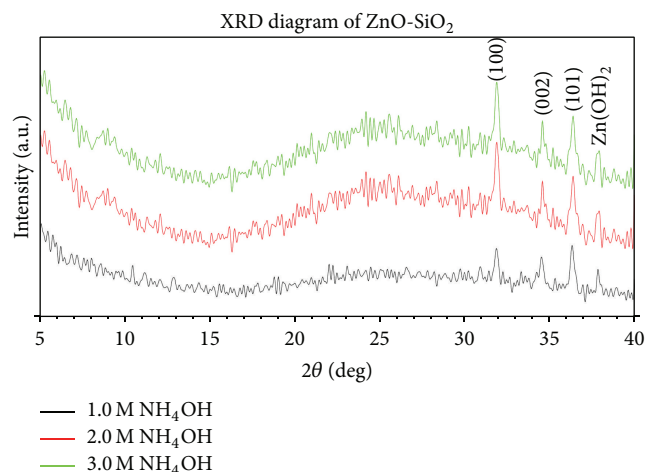


FIGURE 9: X-ray diffraction plot of the as-grown ZnO-SiO₂ on glass substrate using 1.0 M (black), 2.0 M (red), and 3.0 M (green) NH₄OH.

5. Conclusion

In conclusion, the control of the morphology of ZnO-SiO₂ was presented by changing initial OH⁻ ion concentration. For a better understanding of the growth of ZnO-SiO₂, we demonstrated first the effect of SiO₂ on the morphology of ZnO followed by the influence of varying OH⁻ ion concentration on its size and shape. It was found that bare ZnO rods exhibit hexagonal morphology having a *c*-axis preferred growth direction. Addition of amorphous silica to the ammonium-zincate bath for ZnO-SiO₂ synthesis resulted in a remarkable change of morphology from hexagonal to “pointed tip” rods. Increasing initial OH⁻ ion concentration produces “flower-like” structure having hemispherical top surface but shorter rods due to surface capping of silica to ZnO. Infrared spectroscopic study confirms the formation of ZnO-SiO₂ from the functional groups present. Phase analysis by XRD suggested a wurtzite crystal structure of ZnO-SiO₂ was developed. Preliminary studies on the gas sensing capability and testing of the optical and electrical properties for solar cell application of the produced ZnO-SiO₂ are currently being conducted.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

The authors would like to thank the Commission on Higher Education-Philippine Higher Education Research Network (CHED-PHERNet) through the Office of the Vice Chancellor for Research and Extension of MSU-IIT for the financial support of this research study.

References

- [1] G. Jia, Y. Wang, and J. Yao, “Fabrication and optical properties of well-aligned ZnO nanorods on sapphire prepared by chemical bath deposition,” *Digest Journal of Nanomaterials and Biostructures*, vol. 7, no. 1, pp. 261–267, 2012.
- [2] C. Liu, L. Zheng, Z. Gao, Y. Gan, J. Zhang, and C. Li, “Effects of annealing conditions on ZnO buffer layer for inverted polymer solar cells,” *Optics and Photonics Journal*, vol. 3, no. 2, pp. 222–226, 2013.
- [3] N. W. Emanetoglu, J. Zhu, Y. Chen, J. Zhong, Y. Chen, and Y. Lu, “Surface acoustic wave ultraviolet photodetectors using epitaxial ZnO multilayers grown on r-plane sapphire,” *Applied Physics Letters*, vol. 85, no. 17, pp. 3702–3704, 2004.
- [4] M. Suchecka, S. Christoulakis, K. Moschovis, N. Katsarakis, and G. Kiriakidis, “ZnO transparent thin films for gas sensor applications,” *Thin Solid Films*, vol. 515, no. 2, pp. 551–554, 2006.
- [5] A. R. Kim, J.-Y. Lee, B. R. Jang, H. S. Kim, N. W. Jang, and J. Y. Lee, “Effect of Zn²⁺ source concentration on hydrothermally grown ZnO nanorods,” *Journal of Nanoscience and Nanotechnology*, vol. 11, no. 7, pp. 6395–6399, 2011.
- [6] M. A. Moghri Moazzen, S. M. Borghei, and F. Taleshi, “Change in the morphology of ZnO nanoparticles upon changing the reactant concentration,” *Applied Nanoscience*, vol. 3, no. 4, pp. 295–302, 2013.
- [7] A. Laurentowska and T. Jesionowski, “ZnO-SiO₂ oxide composites synthesis during precipitation from emulsion system,” *Physicochemical Problems of Mineral Processing*, vol. 48, no. 1, pp. 63–76, 2012.
- [8] J. Sójka-Ledakowicz, J. Olczyk, A. Waławska, A. Laurentowska, A. Kolodziejczak-Radzimska, and T. Jesionowski, “Modification of textile products with nanosized zinc oxide and ZnO-SiO₂ oxide composite,” *Przemysł Chemiczny*, vol. 89, no. 12, pp. 1648–1652, 2010.
- [9] H. Barani, “Preparation of antibacterial coating based on in situ synthesis of ZnO/SiO₂ hybrid nanocomposite on cotton fabric,” *Applied Surface Science*, vol. 320, pp. 429–434, 2014.
- [10] M. Abdullah, S. Shibamoto, and K. Okuyama, “Synthesis of ZnO/SiO₂ nanocomposites emitting specific luminescence colors,” *Optical Materials*, vol. 26, no. 1, pp. 95–100, 2004.
- [11] N. Hagura, T. Takeuchi, S. Takayama, F. Iskandar, and K. Okuyama, “Enhanced photoluminescence of ZnO-SiO₂ nanocomposite particles and the analyses of structure and composition,” *Journal of Luminescence*, vol. 131, no. 1, pp. 138–146, 2011.
- [12] J. Zhai, X. Tao, Y. Pu, X.-F. Zeng, and J.-F. Chen, “Core/shell structured ZnO/SiO₂ nanoparticles: preparation, characterization and photocatalytic property,” *Applied Surface Science*, vol. 257, no. 2, pp. 393–397, 2010.
- [13] Y.-L. Tang, Z.-J. Li, J.-Y. Ma, Y.-G. Guo, Y.-Q. Fu, and X.-T. Zu, “Ammonia gas sensors based on ZnO/SiO₂ bi-layer nanofilms on ST-cut quartz surface acoustic wave devices,” *Sensors and Actuators B: Chemical*, vol. 201, pp. 114–121, 2014.
- [14] Y. Sun, G. M. Fuge, and M. N. R. Ashfold, “Growth of aligned ZnO nanorod arrays by catalyst-free pulsed laser deposition methods,” *Chemical Physics Letters*, vol. 396, no. 1–3, pp. 21–26, 2004.
- [15] J.-J. Wu and S.-C. Liu, “Low-temperature growth of well-aligned ZnO nanorods by chemical vapor deposition,” *Advanced Materials*, vol. 14, no. 3, pp. 215–218, 2002.
- [16] W. I. Park, D. H. Kim, S.-W. Jung, and G.-C. Yi, “Metalorganic vapor-phase epitaxial growth of vertically well-aligned ZnO

- nanorods," *Applied Physics Letters*, vol. 80, no. 22, pp. 4232–4234, 2002.
- [17] J.-S. Lee, K. Park, M.-I. Kang et al., "ZnO nanomaterials synthesized from thermal evaporation of ball-milled ZnO powders," *Journal of Crystal Growth*, vol. 254, no. 3-4, pp. 423–431, 2003.
- [18] Q. X. Zhao, P. Klason, and M. Willander, "Growth of ZnO nanostructures by vapor-liquid-solid method," *Applied Physics A*, vol. 88, no. 1, pp. 27–30, 2007.
- [19] M. H. Huang, Y. Wu, H. Feick, N. Tran, E. Weber, and P. Yang, "Catalytic growth of zinc oxide nanowires by vapor transport," *Advanced Materials*, vol. 13, no. 2, pp. 113–116, 2001.
- [20] A. D. M. V. Peguit, R. T. Candidato Jr., R. M. Vequizo et al., "Controlling the growth of ZnO-SiO₂ nanostructures using Pt-coated Si substrate," *Applied Mechanics and Materials*, vol. 548-549, pp. 354–357, 2014.
- [21] E. Pantohan, R. Candidato, and R. Vequizo, "Surface modification of nanostructured hexagonal ZnO powder using amorphous silica powder via low temperature sol-gel process," *Journal of Applied Science and Agriculture*, vol. 9, no. 11, pp. 389–394, 2014.
- [22] R. N. Gayen, K. Sarkar, S. Hussain, R. Bhar, and A. K. Pal, "ZnO films prepared by modified sol-gel technique," *Indian Journal of Pure and Applied Physics*, vol. 49, no. 7, pp. 470–477, 2011.
- [23] X. Ying-Mei, Q. Ji, H. De-Min et al., "Preparation of amorphous silica from oil shale residue and surface modification by silane coupling agent," *Oil Shale*, vol. 27, no. 1, pp. 37–46, 2010.
- [24] K. T. Simfroso, A. C. Alguno, F. R. Bagsican et al., "Growth mechanism of chemically prepared ZnO-SiO₂ nanostructures grown on glass and silicon substrates," *IOP Conference Series: Materials Science and Engineering*, vol. 79, Article ID 012031, 6 pages, 2015.
- [25] A. D. M. V. Peguit, R. T. Candidato Jr., F. R. Bagsican et al., "Growth of chemically deposited ZnO and ZnO-SiO₂ on Pt buffered Si substrate," *IOP Conference Series: Materials Science and Engineering*, vol. 79, Article ID 012026, 6 pages, 2015.
- [26] S. Musić, N. Filipović-Vinceković, and L. Sekovanić, "Precipitation of amorphous SiO₂ particles and their properties," *Brazilian Journal of Chemical Engineering*, vol. 28, no. 1, pp. 89–94, 2011.
- [27] K. S. Babu, A. R. Reddy, and K. V. Reddy, "Controlling the size and optical properties of ZnO nanoparticles by capping with SiO₂," *Materials Research Bulletin*, vol. 49, no. 1, pp. 537–543, 2014.



Hindawi

Submit your manuscripts at
<http://www.hindawi.com>

