ACADEMIA ROMÂNĂ

*Revue Roumaine de Chimie*

http://web.icf.ro/rrch/

*Rev. Roum. Chim.,* **2018**, *63*(2), 103-106

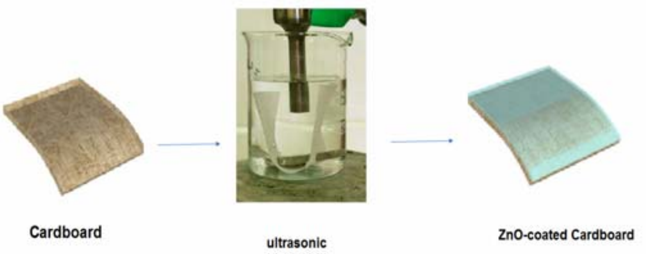
# COATING OF ZnO NANOPARTICLES ON CARDBOARD FOR FOOD PACKAGING APPLICATION

Hamid Reza GHORBANI*

Department of Chemical Engineering, Qaemshahr Branch,
Islamic Azad University, Qaemshahr, Iran.

*Received March 27, 2017*

The most common type of packaging is a cardboard box. As one of the main packaging materials in medical and food industry, cardboard is capable to bacterial pollution. Therefore, coated cardboard with antibacterial properties of ZnO nanoparticles could be an alternative to other food conservation approaches. In this work, the ZnO nanoparticles were synthesized by precipitation technique using NaOH as precipitating agent and zinc nitrate as zinc source in aqueous solution. Then, the nanoparticles layer was successfully coated onto the surface of cardboard using ultrasonic radiation. The products are characterized using XRD analysis and transmission electron microscopy (TEM). In addition, characterization of ZnO nanoparticles is performed by UV-Vis spectroscopy and dynamic light scattering (DLS). The antibacterial activity of the covered cardboard in contrast to *Escherichia coli* and *Staphylococcus aureus* was measured by agar diffusion method. It was found that the coated cardboard shows perfect antibacterial activity against both *S. aureus* and *E. coli*. This work displays the possible use of the covered cardboard as a food antibacterial packing material for longer shelf life.




## INTRODUCTION

Research in the field of synthesis methodology of nanoparticles is generally focused on controlling their structure, size and shape. Each of these factors is an important element to specify the properties of materials that result in various industrial uses. [1,2] Zinc oxide, with its distinctive chemical and physical properties, such as great electrochemical coupling factor, high chemical stability and wide range of radiation absorption, is a multifunctional substance.[3,4] In recent years, it was found that ZnO nanoparticles are useful for many applications in different ranges because of their more suitable chemical and physical properties against bulk ZnO.[5] Antibacterial activity of ZnO nanoparticles has taken major attention universal particularly by the application of nanotechnology to synthesize nanoparticles. Many microorganisms exist in the range from hundreds of nanometers to tens of micrometers. ZnO nanoparticles display attractive antibacterial properties because of increased specific surface area. ZnO is a bio-safe substance that contains photocatalysis and photo-oxidizing properties on chemical and biological kinds.[6,7] One key application of the ZnO nanoparticles as an antibacterial agent is in food packaging industry.[8] As one of the main packaging materials in medical and food industry, paper is capable to bacterial pollution. Therefore, coated paper with antibacterial

* Corresponding author: hamidghorbani6@gmail.com

properties of ZnO nanoparticles could be an alternative to other food conservation approaches employing radiation, low temperature storage, heat treatment, or the introduction of antibacterial additives. Nanomaterial coated papers have been also used newly for developing easy, fast and disposable biosensors based techniques for detection of toxins and antigens as well as antibacterial surfaces.[9]

It is confirmed that the different applications of ZnO nanoparticles depend upon the control of both chemical and physical properties.[10] This has led to the growth of a great variety of methods for synthesizing the material. Hong *et al.* used a controlled precipitation method. The process of precipitating ZnO was accomplished using zinc acetate ($Zn(CH_3COO)_2{\cdot}H_2O$) and ammonium carbonate $(NH4)_2CO_3$. [6] In another work, an easy precipitation technique for the synthesis of ZnO was performed by Lanje *et al.*[11]

In the current study, we employed NaOH as a precipitating agent and zinc nitrate as an initial reagent. On the other hand, it includes *in situ* generation of nanoparticles in the reaction container and immediate sediment on the cardboard surface. The results displayed ZnO nanoparticles size and therefore its coating can be controlled by changing the precursor and precipitating agent concentrations. This ZnO nanoparticles-coated cardboard shows antibacterial properties against *Escherichia coli* (*E. coli*) as well as against *Staphylococcus aureus* (*S. aureus*) bacteria.

## RESULTS AND DISCUSSION

The UV–Vis spectrum of the solution at different wavelengths ranging from 200 to 500 nm showed a strong absorption peak centered at 369 nm indicating the formation of ZnO (Fig. 1). The size of nanoparticles synthesized is measured by dynamic light scattering (DLS). The particle size distribution is unimodal and an average particle size of 75 nm was determined for the ZnO nanoparticles (Fig. 2).

To confirm the coating of the cardboard surface with ZnO nanoparticles the X-ray diffraction technique was used. The XRD pattern recorded on ZnO nanoparticles coated cardboard obtained after 30 min of sonication are shown in Figure 3.The XRD pattern recorded for ZnO nanoparticles coated cardboard showed peaks at 2θ value of 31.7° (100), 34.4° (002), 36.2° (101), 47.5 °(102), 56.6° (110), 62.8° (103), 66.4° (200), 67.9° (112) and 69.1° (201) characteristic of ZnO and were in good agreement with data reported in the literature. [9, 11] The remaining peaks in the XRD pattern are attributed to cellulose and $CaCO_3$. In addition, TEM results also support this observation. The ZnO nanoparticles coated cardboard was studied by transmission electron microscopy (TEM) and the images of Fig. 4 show the presence of ZnO nanoparticles on the cardboard surface.

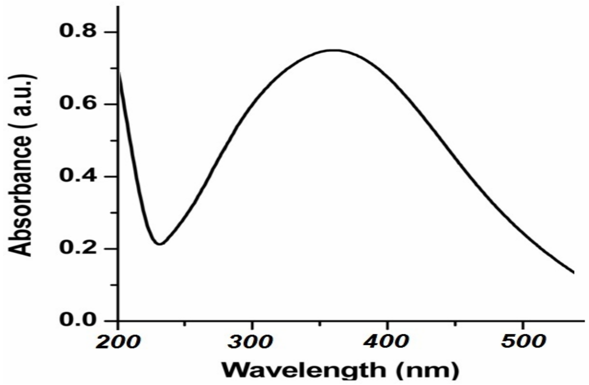



Fig. 1 – UV–vis spectrum of ZnO nanoparticles solution.

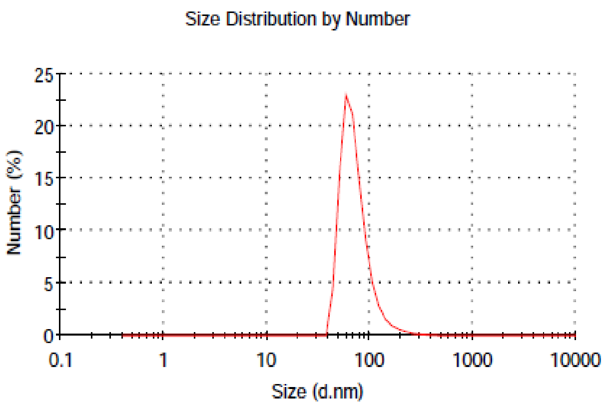



Fig. 2 – The size distribution of ZnO nanoparticles by number.

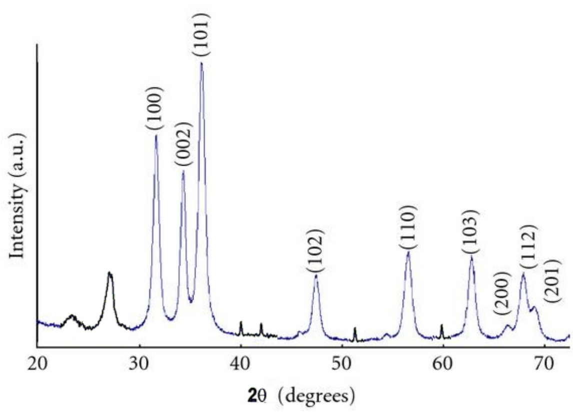



Fig. 3 – X-ray diffraction pattern of ZnO nanoparticles coated cardboard.

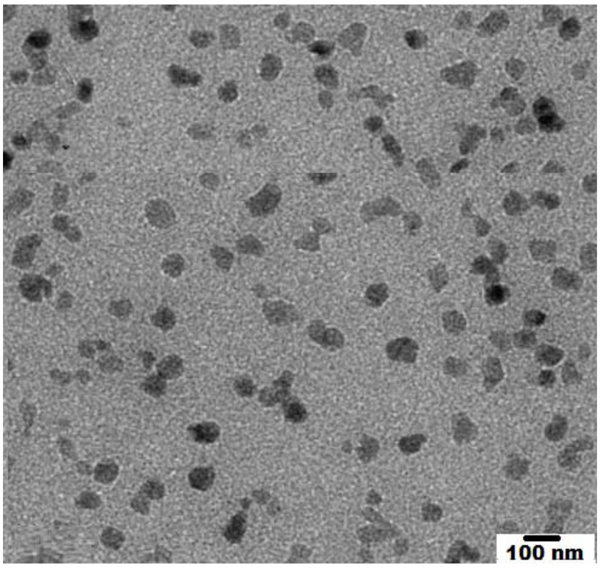



Fig. 4 – TEM image of ZnO nanoparticles coated cardboard.

The ZnO nanoparticles show an effective antibacterial activity against gram negative and gram positive bacteria. The result suggests that ZnO nanoparticles undergo a contact with bacterial wall and showed the strong action against *E. coli*, and *S. aureus*. In this work, the ZnO nanoparticles coated cardboard was tested on bacterial strains *S. aureus* and *E. coli*. The formation of clear zone around the hole is a sign of antibacterial activity. As can be realized, the antibacterial activity of nanoparticles coated cardboard on S. aureus and E. coli is more than tetracycline and colistin on *S. aureus* and *E. coli* (Figure not shown). The zone of inhibition of diameters was determined. However, it is obvious that the ZnO nanoparticles coated cardboard shows good antibacterial activity against both *S. aureus* and *E. coli*. The results have been summarized in Table 1.

*Table 1*

The antibacterial activity of the ZnO nanoparticles coated cardboard, zone of inhibition (mm)

| Organism | Tetracycline | Colistin | ZnO-coated cardboard | Control sample |
|---|---|---|---|---|
| *S. aureus* | 1 | - | 2 | - |
| *E. coli* | 1 | 1 | 2 | - |

## EXPERIMENTAL

### Materials

Zinc nitrate as the precursor and NaOH as a precipitating agent were prepared from Sigma-Aldrich. Cardboard was purchased from ICFP, Iran.

### Synthesis and Coating of Cardboard

ZnO nanoparticles were synthesized by precipitation technique using NaOH as precursors and zinc nitrate. In this work, the aqueous solution of zinc nitrate (0.2 M) and the solution of NaOH (0.4 M) were prepared with deionized water, respectively. The NaOH solution was gently added into zinc nitrate solution at room temperature under forceful mixing, which led to white suspension formation. The white suspension was centrifuged at 5 000 rpm for 20 min and washed three times with distilled water, and then washed with alcohol. The produced nanoparticles were calcined at 520 °C in air for 3 hr. Uv-vis spectroscopy (Jenway, 6505, UK) was applied to confirm the existence of nanoparticles. This technique is used widely for the determination of nanoparticles size in colloidal solution. The average size was determined by dynamic light scattering, Nano ZS (red badge) ZEN 3 600, Malvern, UK (DLS). The ZnO nanoparticles suspension was produced in deionized water using ultrasonic for 15 min. Then the cardboard was held immersed in a solution with a Teflon disk (D = 2 cm) to prevent it from floating. Ammonia was added slowly to the ZnO nanocolloid and sonicated for 30 min. Subsequently the coated cardboard was removed and dried at 75°C prior to characterization.

### Characterization of Coatings

To confirm the coating of ZnO nanoparticles on the cardboard surface, the XRD (S-4160, Hitachi, Japan) investigation was used. The morphology and the size of the ZnO nanoparticles were studied by means of transmission electron microscopy, 906E, LEO, Germany (TEM).

### Antibacterial activity

The disc diffusion method was used to specify the antibacterial activity of ZnO-coated cardboard in contrast to *S. aureus* and *E. coli*. This method was performed in nutrient agar medium solid agar Petri dish. Samples of ZnO-coated cardboard (1 cm²), two antibiotics (tetracycline and colistin) and control sample were placed in the nutrient agar Petri dish and kept for incubation at 37°C for 1 day. Zones of inhibition for two antibiotics, ZnO-coated cardboard and control sample were measured. The experiments were accomplished three times, and the average values of zone diameter were determined.

## CONCLUSIONS

In the current work, the ZnO nanoparticles were successfully synthesized by a precipitation technique using NaOH as precipitating agent and zinc nitrate as zinc source in aqueous solution. The average size of the produced ZnO nanoparticles was about 75 nm. These ZnO nanoparticles were successfully coated onto the surface of cardboard using ultrasonic radiation. The coated cardboard established good antibacterial activity in contrast to gram negative and gram positive bacteria, proposing capability application as food conservation substance for longer shelf life and avoidance of cross pollution.

## REFERENCES

1. E. A. Chandross and R. D. Miller, *Chem. Rev.*, **1999**, *99*, 1641-1642.
2. R. Djalali, J. Samson and H. Matsui, *J. Am. Chem. Soc.*, **2004**, *126*, 7935-7939.
3. D. Segets, J. Gradl, R. K. Taylor, V. Vassilev and W. Peukert, *W. ACS Nano*, **2009**, *3*, 1703-1710.
4. R. Mueller, L. Madler and S. E. Pratsinis, *Chem. Eng. Sci.*, **2003**, *58*, 1969-1976.
5. N. M. Franklin, N. J. Rogers, S. C. Apte, G. E. Batley and G. E. Gadd, *Environ. Sci. Tech.*, **2007**, *41*, 8487-8493.
6. M. A. Sayyadnejad, H. R. Ghaffarian and M. Saeidi, *Int. J. Environ. Sci. Tech.*, **2008**, *5*, 565-569.
7. A. Sirelkhatim, S. Mahmud, A. Seeni, N. H. M. Kaus, L. C. Ann, S. Khadijah M. Bakhori, H. Hasan and D. Mohamad, *Nano-Micro Lett.*, **2015**, *7*, 219-242.
8. C. Rode, M. Zieger, R. Wyrwa, S. Thein, C. Wiegand, M. Weiser, A. Ludwig, D. Wehner and U. Hipler, *Prog. Nat. Sci.*, **2012**, *22,* 693–700.
9. B. Pang, J. Yan, L. Yao, H. Liu, J. Guan, H. Wang and H. Liu, *RSC Adv.*, **2016**, *6*, 9753-9759.
10. R. Wahab, S.G. Ansari, Y. Kim, H. Seo and H. Shin, *Appl. Surf. Sci.*, **2007**, *253*, 7622–7626.
11. J. Ma, W. Zhu, Y. Tian and Z. Wang, *Nanoscale Res Lett.*, **2016**, *11*, 226-231.