A study on properties of polymeric films incorporated with silver-coated TiO_2 nano particles

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Abstract

In this research, Low-density polyethylene (LDPE) nanocomposite polymeric films containing different concentrations of silver (Ag) nanoparticles (NPs) and TiO_2 were manufactured via extrusion and subsequently characterized. Silver/TiO_2 surfaces have advantageous properties such as visible light photo catalysis, biological compatibility, and antimicrobial activity. The synthesis of polymer-Ag NPs and Ag NPs on TiO_2 are also summarized because of their industrial and environmental importance[1]. In the present study, the morphological, mechanical, and optical performance of the nanocomposite polymeric films is investigated.

Keywords

Low-density polyethylene, polymeric films, TiO_2, silver, SEM, Mechanical and Optical properties.

Introduction

Polymeric films and also synthetic polymer composite materials play an important role in food packaging and used as structural components because their mechanical properties, versatile processing techniques, chemical inertness and stability, preservatives, oxygen absorbers, water vapor absorbers and reduced cost [2-6]. Moreover the final properties of polymer nanocomposites depend strongly on the properties of the filler such as mechanical, thermal, optical and electrical properties of polymers. Further the chemical reduction of metal salts is the simplest, most cost-effective and commonly used technique to synthesis metal nanoparticles (NPs) at large scale [7]. Further**,** nanotechnology involves the tailoring of materials at atomic level to attain unique properties, which can be suitably manipulated for the desired applications[8]. For example some metallic nanoparticles such as silver, gold, zinc, or metal oxides have been in the center of attention of researchers to produce various active packaging [9]. Among various metal and metal oxide materials being used for nanocomposite film, silver (Ag), and titanium (TiO_2) are particularly important [10]. Hence the synthesis of polymer-Ag NPs and Ag NPs on TiO_2 are also summarized because of their industrial and environmental importance[1]. Titanium dioxide (TiO_2) nanoparticles are porous and inorganic in nature, which is often used as a filler and/or pigment, can also be effective as a typical absorber that selectively absorbs UV light and reemits it at a less harmful wavelength, mainly as heat [11]. In addition TiO_2 is often used as a catalytic support because it is a semiconductor with great optical, electrical and photosensitive for its outstanding photo-induced oxidation and reduction characteristics [10]. Silver has been used as an additive in various polymers and also Some silver-containing fillers commercially available, such as zirconium phosphate or titanium dioxide, as well as some zeolites have been used as silver carriers

[12]. Thus, silver nanocomposites (polymer composites containing silver nanoparticles) have attracted significant interest in the medical industry, applied microbiology, active food packaging ,photo activity of semiconductor and photo catalysis antibacterial activity [10, 13].

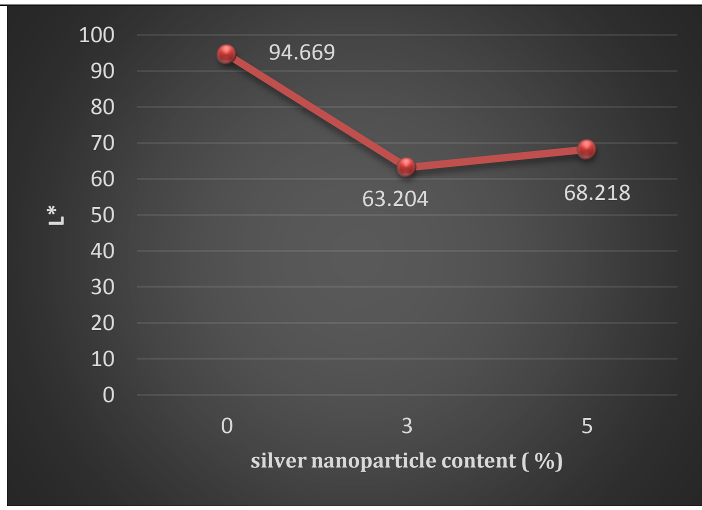
Polyethylene used as a polymeric film in this article. Low-density polyethylene (LDPE) is the most widely used among thermoplastics, especially for packaging and construction applications due to its acceptable flexibility, transparency, process ability, thermal stability, environmental recyclability, and low cost properties [14]. In this study, the effects of TiO_2/Ag nanoparticle dosage on the physical mechanical, and optical properties of the nanocomposite films will be discussed.

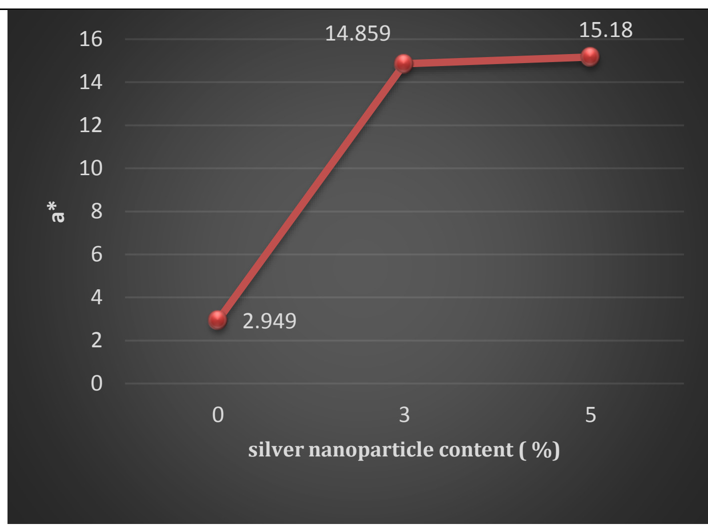
Experimental Section

Low density polyethylene (grade 75) and TiO_2/Ag nanoparticle with particle diameter less than 70 nm were used in this study. The TiO_2/Ag nanoparticles were mixed with LDPE granule in a twin screw extruder. Paraffin (4%) was also used into the extruder as compatibiliser. Various levels of the produced master batches were individually added to the LDPE granule, so that the TiO_2/Ag nanoparticles contents were selected as 3 and 5% based on the total formulation. The process was performed in a single screw extruder and finally nanocomposite films with different TiO_2/Ag loadings were prepared.

Results and Discussion

The values for $L^*a^* b^*$ are given in Figure 1. According to the figure, the color measurement showed no notable change in color parameter when the compatibiliser increases. Nevertheless, by increases the nanoparticles content, the color of the composite films a little changes. In another words, the lightness of the pure LDPE films decreases by increasing the TiO_2/Ag nanoparticles. In addition, a^* values indicate that the blank samples tend to be more reddish.





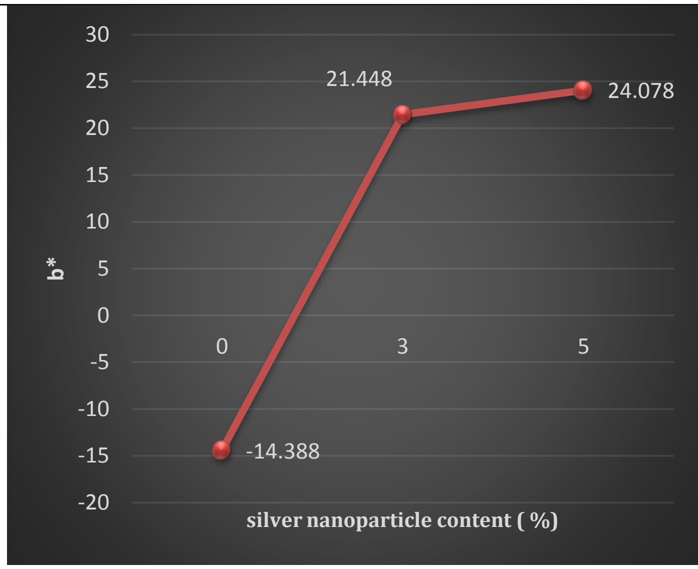


Figure 1: Color parameters of the LDPE films at different levels of TiO_2/Ag nanoparticles (no compatibiliser)

Tensile strength of the LDPE films with 0, 3, and 5% TiO_2/Ag nanoparticles with 0, and 4% paraffin as a compatibiliser shows in the Figure 2. Addition of 3% of TiO_2/Ag nanoparticles increases the tensile strength of nanocomposite film with 4% paraffin. Figure 2 shows that incorporation of paraffin compatibiliser into the polymeric film increases the tensile strength of 3% TiO_2/Ag nanoparticles filled LDPE films. In another words, increase of tensile strength due to high surface area of fillers which create interactions with matrix in nano scale [15].

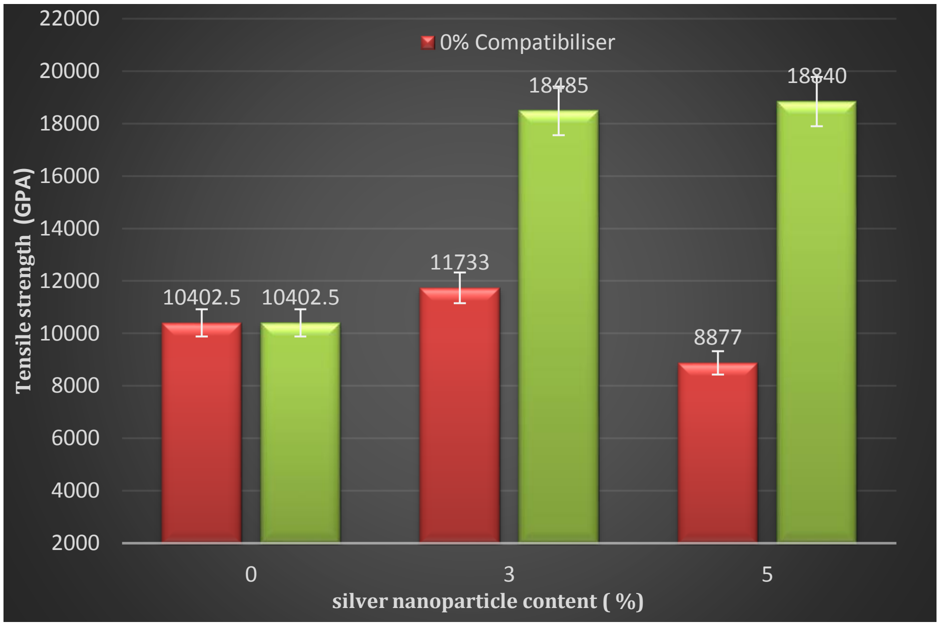


Figure 2: Tensile strength of the LDPE films at different levels of TiO_2/Ag nanoparticles and paraffin compatibiliser.

According to mechanical results, the SEM image of TiO_2/Ag nanoparticles with 4% compatibiliser in Figure 3 showing well dispersed throughout the LDPE matrix. On the other hand, nanoparticles are fully exfoliated and uniformly dispersed in the polymeric matrix by compatibiliser.

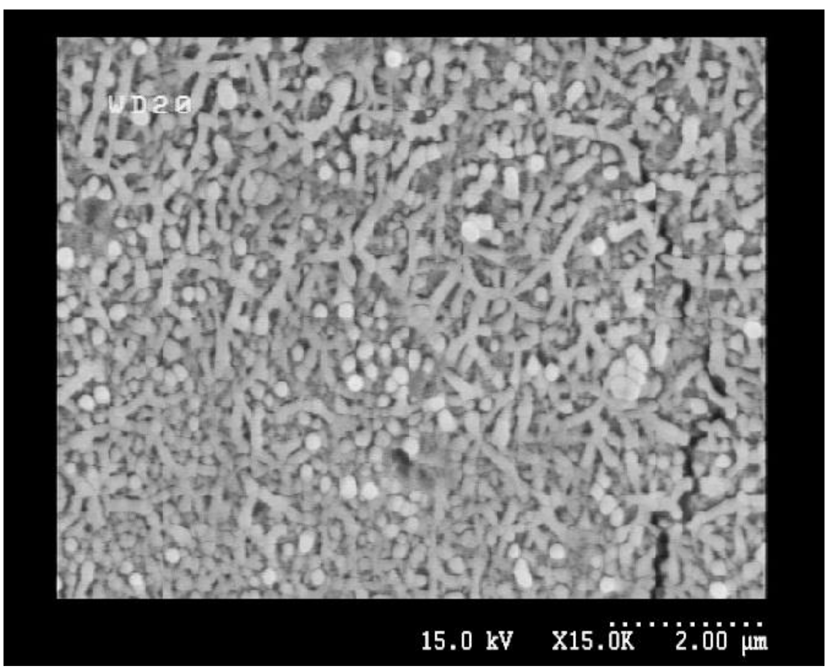


Figure 3: SEM micrographs of nanocomposite films at 3% silver nanoparticles and 4% paraffin.

References

1. Sharma, V.K., R.A. Yngard, and Y. Lin, *Silver nanoparticles: green synthesis and their antimicrobial activities.* Advances in colloid and interface science, 2009. **145**(1): p. 83-96.
2. Mihindukulasuriya, S. and L.-T. Lim, *Nanotechnology development in food packaging: A review.* Trends in Food Science & Technology, 2014. **40**(2): p. 149-167.
3. Hu, K., D.D. Kulkarni, I. Choi, and V.V. Tsukruk, *Graphene-polymer nanocomposites for structural and functional applications.* Progress in Polymer Science, 2014. **39**(11): p. 1934-1972.
4. Eslami, M., M. Bayat, A.S.M. Nejad, A. Sabokbar, and A.A. Anvar, *Effect of polymer/nanosilver composite packaging on long-term microbiological status of Iranian saffron (Crocus sativus L.).* Saudi journal of biological sciences, 2016. **23**(3): p. 341-347.
5. Zapata, P.A., M. Larrea, L. Tamayo, F.M. Rabagliati, M.I. Azócar, and M. Páez, *Polyethylene/silver-nanofiber composites: A material for antibacterial films.* Materials Science and Engineering: C, 2016. **69**: p. 1282-1289.
6. Beigmohammadi, F., S.H. Peighambardoust, J. Hesari, S. Azadmard-Damirchi, S.J. Peighambardoust, and N.K. Khosrowshahi, *Antibacterial properties of LDPE nanocomposite films in packaging of UF cheese.* LWT-Food Science and Technology, 2016. **65**: p. 106-111.
7. Azlin-Hasim, S., M.C. Cruz-Romero, M.A. Morris, S.C. Padmanabhan, E. Cummins, and J.P. Kerry, *The Potential Application of Antimicrobial Silver Polyvinyl Chloride Nanocomposite Films to Extend the Shelf-Life of Chicken Breast Fillets.* Food and Bioprocess Technology, 2016. **9**(10): p. 1661-1673.
8. Shrivastava, S., T. Bera, A. Roy, G. Singh, P. Ramachandrarao, and D. Dash, *Characterization of enhanced antibacterial effects of novel silver nanoparticles.* Nanotechnology, 2007. **18**(22): p. 225103.
9. Azlin-Hasim, S., M.C. Cruz-Romero, M.A. Morris, E. Cummins, and J.P. Kerry, *Effects of a combination of antimicrobial silver low density polyethylene nanocomposite films and modified atmosphere packaging on the shelf life of chicken breast fillets.* Food Packaging and Shelf Life, 2015. **4**: p. 26-35.
10. Li, L., C. Zhao, Y. Zhang, J. Yao, W. Yang, Q. Hu, C. Wang, and C. Cao, *Effect of stable antimicrobial nano-silver packaging on inhibiting mildew and in storage of rice.* Food chemistry, 2017. **215**: p. 477-482.
11. Krehula, L.K., A. Papić, S. Krehula, V. Gilja, L. Foglar, and Z. Hrnjak-Murgić, *Properties of UV protective films of poly (vinyl-chloride)/TiO2 nanocomposites for food packaging.* Polymer bulletin, 2017. **74**(4): p. 1387-1404.
12. Sánchez-Valdes, S., H. Ortega-Ortiz, L. Ramos-de Valle, F. Medellín-Rodríguez, and R. Guedea-Miranda, *Mechanical and antimicrobial properties of multilayer films with a polyethylene/silver nanocomposite layer.* Journal of applied polymer science, 2009. **111**(2): p. 953-962.
13. Jokar, M., K. Loeschner, and A.M. Nafchi, *Modeling of Silver Migration from Polyethylene Nanocomposite Packaging into a Food Model System Using Response Surface Methodology.* International Journal of Food Engineering, 2016. **2**(2): p. 96-102.
14. Metak, A.M., F. Nabhani, and S.N. Connolly, *Migration of engineered nanoparticles from packaging into food products.* LWT-Food Science and Technology, 2015. **64**(2): p. 781-787.
15. Mahdavi, H., H. Mirzadeh, M.J. Zohuriaan-Mehr, and F. Talebnezhad, *Poly (vinyl alcohol)/chitosan/clay nano-composite films.* J Am Sci, 2013. **9**: p. 203-214.