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A review on polymer - ceramics new bionanocomposites for antibacterial applications

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Abstract

The nanocomposites applications are quite promising in the fields of packaging, medicine, optical integrated circuits, coatings, drug delivery, sensors, aerospace, packaging materials, adhesives, consumer goods. Etc. This review includes new nanocomposites consist of biopolymer and ceramics nanoparticles for antibacterial applications with high activity, low cost and low weight. The results showed that the nanocomposites have high activity as antibacterial materials.

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Introduction

The studies of metal oxide nanoparticles/polymer nanocomposites are creating increasing attention owing to their possible applications in memory, recording heads, microwave devices and household electronics (Upadhyay *et al.*, 2014). The polymer nanocomposites has been effectively utilized for numerous steady inorganic colloids free from aggregation, like zinc oxide, titanium oxide, metal and magnetic nanoparticles (Jaleh *et al.*, 2011). Titanium dioxide is one of the promising materials used in wide range applications due to its optical and electronic properties (Omar, &Matoussi, 2012). There are some methods to make polymers antibacterial such as ionizing radiation, but they can be still infected by microorganisms during usage of them.The best and easy way to obtain antibacterial polymers is melt mixing of polymers with antibacterial agents (Altan, & Yildirim, , 2014). Antibacterial agents like TiO_2 has photocatalytic activity under UV, light so daylight or UV light is needed to make them active in killing bacteria (Brayner, *et al.,* 2006).The (TiO_2-SiC) indicated beneficial photo catalytic performance as compared to TiO_2 nanoparticles (Hao, *et. al* 2014). The nanocomposites have good properties which are made it used in different applications such as: humidity sensors (Ahmed *et al.*, 2019; Agool *et al.*, 2017; Hadi and Hashim, 2017; Hashim and Hadi , 2018; Hashim and Hadi , 2018), antibacterial (Kadhim *et al.*, 2017; Kadhim *et al.*, 2016; Hashim *et al.*, 2018; Rashid *et al.*, 2018; Ahmed *et al.*, 2019), pressure sensors (Hamad and Hashim, 2018; Hashim and Hamad, 2018; Hashim and Hadi, 2017; Hashim and Hadi , 2018), radiation shielding (Hashim and Hadi , 2017; Agool *et al.*, 2017), ...etc. Figure (1) representation of bacterial photo killing using TiO_2.

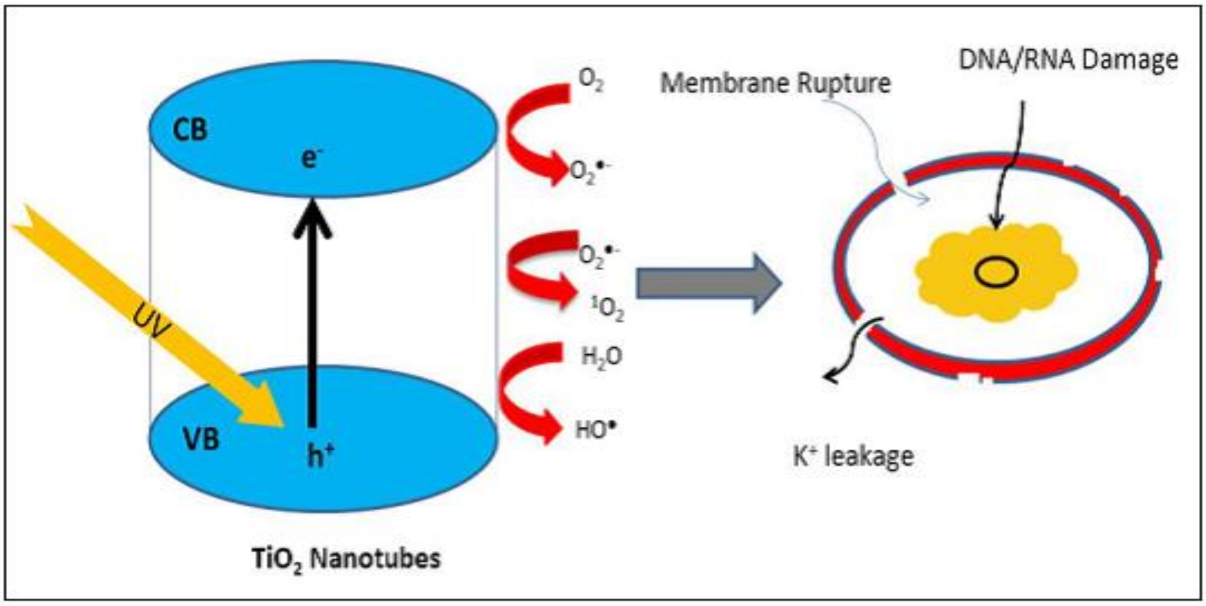

Fig. 1. Schematic representation of bacterial photokilling using TiO_2 (Etacheri, *et al.* 2015).

Nanomedicine

Nanotechnology provides the ability to engineer the materials properties by controlling their size (Etheridge *et al.,* 2013). It producing major advances in energy, including high-performance batteries and economic solar cells; electronics, with single-atom transistors and ultrahigh density data storage; food and agriculture, increased screening for contaminants and offering smart delivery of nutrients. However, two of the most promising and exciting domains for advancement are medicine and health. It offers potential developments in medical imaging and diagnosis, pharmaceuticals, cancer treatment, tissue regeneration and implantable materials (Ruhal *et al.,* 2013). Applying nanotechnology for treatment, monitoring, control of diseases and diagnosis has been referred to as nanomedicine (Kaur *et al.,* 2012).

The new resistant strains development of bacteria to current antibiotics has become a serious problem in public health; therefore, there is incentive to develop new bactericides (Singh *et al.* 2008).

The antibiotics wide scale use in the prevention and treatment of bacterial infections has led to the spread of resistant microorganisms requiring the development of new active molecules against bacteria. Nanoparticles are similar in size to biological macromolecules and smaller than human cells. The development of nanotreatment strategies represents a opportunity to enhance medical treatments, improving prognosis and care for challenging healthcare issues (Monzillo *et al.,* 2014; Ansari, *et al.*, 2011).

Literature Survey

Polymer- ceramics nanocomposites are used for environmental and emission monitoring, automotive, domestic, industrial and medical applications**.**

Akhavan in 2009. The Ag–TiO_2/Ag/a-TiO_2nanocomposite thin film photocatalyst sensitive to the solar light with an efficient storage of Ag nanoparticles both on the film surface and at interface of the Ag–TiO_2 and a-TiO_2 thin films was simply synthesized by sol–gel. The photo degradation of the thin films was studied by testing its antibacterial activity against E. coli bacteria, in dark and in the visible and the solar light irradiations.

The relative rate of reduction of the viable bacteria for the nanocomposite film ($3.6x10^{-2}$ min^{-1}) was 5.1 times greater than the corresponding value for the a-TiO2 thin film, in dark**.**

Gupta et al. In (2013). Studied the structural and optical properties and comparative photocatalytic activity of TiO_2 and Ag-doped TiO_2 nanoparticles against different bacterial strains under visible-light irradiation.The antimicrobial activity of TiO_2 and Ag-doped TiO_2 nanoparticles (3% and 7%) was investigated against both gram positive (*Staphylococcus aureus*) and gram negative (*Pseudomonas aeruginosa*, *Escherichia coli*) bacteria. As a result, the viability of all three microorganisms was reduced to zero at 60 mg/30 mL culture in the case of both (3% and 7% doping) concentrations of Ag-doped TiO_2nanoparticles. Annealed TiO_2 showed zero viability at 80 mg/30 mL whereas doped Ag-TiO_2 7% showed zero viability at 40 mg/30 mL culture in the case of *P. aeruginosa* only.

*Villatte et al***.** in (2015) .This study enabled to develop an antibacterial coating for stainless steel commonly used in surgical practice. The process using photoactive TiO_2 exposed to ultraviolet irradiation is actually well known and applied widely in disinfection procedures.

The model was effective against the two main bacterial strains involved in pin tract infections. Mechanical tests confirmed the ability of the coating to resist important stresses. Moreover, this type of coating is created by sol-gel dip-coating techniques that are not expensive and easily scalable for industrial application. This new option could prevent pin tract infection, even if heavy optimization work is yet to be done in order to amplify its bactericidal properties.

Feng et al. In (2017). In this study, the antibacterial corrugating medium was prepared by the coating method using nano TiO_2 as the antibacterial agent, and the antibacterial effect was investigated by the inhibition zone method. In addition, the mechanical properties of corrugating medium, such as the thickness, stiffness, bursting strength, tensile strength and folding endurance, were studied under different concentrations of TiO_2 antibacterial agent.

Results showed that the difference of lateral folding endurance was not obvious, but the stiffness, bursting strength, tensile strength and folding endurance were increased obviously with increase concentration of antimicrobial agent. The diameter of inhibition zone was initially increased with the increase concentration of the antimicrobial agent, but decreased when the concentration was more than 0.1 wt%. The maximum diameter was 5.89 mm when the concentration was 0.1 wt%.

Akbarzadeh et al. In (2018). The FeAg bimetallic nanoparticles supported on TiO_2 nanowires (NWs) were synthesized by a facile chemical deposition method. This material subsequently was applied for electrochemical hydrogen storage, photocatalytic degradation of a binary solution of Auramine-O (AO) and Methylene blue (MB) dyes and photocatalytic hydrogen production.It was noteworthy that antibacterial activity experiments illustrated the improved antibacterial activity of Fe__Ag/TiO_2 NPs in comparison to Fe__Ag/TiO_2 NWs because the one-dimensional structure of TiO_2 nanowires makes it difficult to enter the bacterial membrane.

Mirmohseni et al. in (2019).In this study a straightforward approach has been developed for fabricating antibacterial and antistatic epoxy coatings by using polyaniline-chitosan modified TiO_2 ternary nanocomposite. This nanocomposite was synthesized through the following steps. First, chitosan was grafted onto the TiO_2 nanoparticles and then final nanocomposite was prepared via solution polymerization of aniline. Electrical conductivity measurement revealed that nanocomposite with 7.5 wt % of the modified TiO_2 nanoparticles has noticeably higher conductivity compared to polyaniline. Evaluating the coatings' antibacterial property indicated epoxy coatings with the content of ternary nanocomposite show significant bactericidal activity against Gram-positive bacteria and have acceptable antibacterial action against Gram-negative ones. Also, obtained results showed that the ternary nanocomposite would greatly decrease coatings' surface resistivity and when nanocomposite content is about 2 wt % surface resistivity is about $3 \times 10^7\ \Omega\ sq^{-1}$. On the contrary, the coating with nanocomposite loading exhibits improved thermal and mechanical performance compared to the coating made of neat epoxy.

Conclusion

Polymer- ceramics nanocomposites have many modern applications for medicine, biological and industrial fields. The nanocomposites of biopolymer and ceramics nanoparticles can be used for antibacterial applications with high activity, low cost and low weight. The results showed that the nanocomposites have high activity as antibacterial materials.

Reference

Agool IR, Kadhim KJ, Hashim A. 2017. Synthesis of (PVA-PEG-PVP-ZrO_2) Nanocomposites for Energy Release and Gamma Shielding Applications. International Journal of Plastics Technology **21(2).** https://doi.org/10.1007/s12588-017-9196-1.

Agool IR, Kadhim KJ, Hashim A. 2017. Fabrication of new nanocomposites: (PVA-PEG-PVP) blend-zirconium oxide nanoparticles) for humidity sensors. International Journal of Plastics Technology **21(2).** https://doi.org/10.1007/s12588-017-9192-5.

Ahmed H, Abduljalil HM, Hashim A. 2019. Analysis of Structural, Optical and Electronic Properties of Polymeric Nanocomposites/Silicon Carbide for Humidity Sensors. Transactions on Electrical and Electronic Materials. https://doi.org/10.1007/s42341-019-00100-2

Ahmed H, Hashim A, Abduljalil H. 2019. Analysis of Structural, Electrical and Electronic Properties of (Polymer Nanocomposites/ Silicon Carbide) For Antibacterial Application. Egyptian Journal of Chemistry. https://doi.org/10.21608/EJCHEM.2019.6241.1522.

Akbarzadeh R, Ghaedi M, Kokhdan SN, Jannesar R, Sadeghfar F, Sadri F, Tayebi L. 2018. Electrochemical hydrogen storage, photocatalytical and antibacterial activity of FeAg bimetallic nanoparticles supported on TiO_2, International Journal of Hydrogen Energy **43(39),** 18316-18329.

Akhavan O. 2009. Lasting antibacterial activities of Ag–TiO_2/Ag/a-TiO_2nanocomposite thin film photocatalysts under solar light irradiation. Journal of Colloid and Interface Science **336(1),** 117-124.

Altan M, Yildirim H. 2014. Comparison of antibacterial properties of nano TiO_2 and ZnO particle filled polymers. ActaPhysica Polonica A **125(2).**

Ansari MA, Khan HM, Khan AA, Sultan A, Azam A, Shahid M, Shujatullah F. 2011. Antibacterial activity of silver nanoparticles dispersion against MSSA and MRSA isolated from wounds in a tertiary care hospital of North India **2(4),** 34-42.

Brayner R, Ferrari-Iliou R, Brivois N, Djediat S, Benedetti MF, Fiévet F. 2006. Toxicological impact studies based on Escherichia coli bacteria in ultrafine ZnO nanoparticles colloidal medium. Nano letters **6(4),** 866-870.

Etacheri V, Di Valentin C, Schneider J, Bahnemann D, Pillai SC. 2015. Visible-light activation of TiO_2photocatalysts: Advances in theory and experiments. Journal of Photochemistry and Photobiology C: Photochemistry Reviews **25,** 1-29.

Etheridge ML, Campbell SA, Erdman AG, Haynes CL, Wolf SM, McCullough J. 2013. The big picture on nanomedicine: the state of investigational and approved nanomedicine products. Nanomedicine: nanotechnology, biology and medicine **9(1),** 1-14.

Feng Y, Tan H, Li C, Wang Y, Zhang Y, Wen P, Xu L. 2017. Preparation and characterization of nanoTiO_2 antibacterial corrugating medium. Journal of Nanoscience and Nanotechnology **17(12),** 8912-8917.

Gupta K, Singh RP, Pandey A, Pandey A. 2013. Photocatalytic antibacterial performance of TiO_2 and Ag-doped TiO_2 against S. aureus. P. aeruginosa and E. coli. Beilstein journal of nanotechnology **4(1),** 345-351.

Hadi A, Hashim A. 2017. Development of a new humidity sensor based on (carboxymethyl cellulose–starch) blend with copper oxide nanoparticles. Ukrainian Journal of Physics **62(12).** http://dx.doi.org/10.15407/ujpe62.12.1044.

Hamad ZS, Hashim A. 2018. Biopolymer blend or titanium nitride nanoparticles: synthesis and pressure sensor characterization for environmental application. Journal of Biodiversity and Environmental Sciences **13(6).**

Hao D, Yang Z, Jiang C, Zhang J. 2014. Synergistic photocatalytic effect of TiO_2 coatings and p-type semiconductive SiC foam supports for degradation of organic contaminant. Applied Catalysis B: Environmental **144,** 196-202.

Hashim A, Hadi A. 2017. Novel lead oxide polymer nanocomposites for nuclear radiation shielding applications. Ukrainian Journal of Physics **62(11).** http://dx.doi.org/10.15407/ujpe62.11.0978.

Hashim A, Hadi A. 2018. Novel Pressure Sensors Made From Nanocomposites (Biodegradable Polymers–Metal Oxide Nanoparticles): Fabrication and Characterization. Ukrainian Journal of Physics **63(8).** https://doi.org/10.15407/ujpe63.8.754

Hashim A, Hadi A. 2017. Synthesis and characterization of novel piezoelectric and energy storage nanocomposites: biodegradable materials–magnesium oxide nanoparticles. Ukrainian Journal of Physics **62(12).** http://dx.doi.org/10.15407/ujpe62.12.1050.

Hashim A, Hadi Q. 2018. Structural, electrical and optical properties of (biopolymer blend/ titanium Carbide) nanocomposites for low cost humidity sensors. Journal of Materials Science: Materials in Electronics **29,** 11598–11604. https://doi.org/10.1007/s10854-018-9257-z.

Hashim A, Hadi Q. 2018. Synthesis of Novel (Polymer Blend-Ceramics) Nanocomposites: Structural, Optical and Electrical Properties for Humidity Sensors. Journal of Inorganic and Organometallic Polymers and Materials **28(4).** https://doi.org/10.1007/s10904-018-0837-4.

Hashim A, Agool IR, Kadhim KJ. 2018. Novel of (Polymer Blend-Fe_3O_4) Magnetic Nanocomposites: Preparation and Characterization for Thermal Energy Storage and Release, Gamma Ray Shielding, Antibacterial Activity and Humidity Sensors Applications. Journal of Materials Science: Materials in Electronics **29(12).** https://doi.org/10.1007/s10854-018-9095-z

Hashim A, Hamad ZS. 2018. Low cost and flexible biopolymers (polyvinyl alcohol-poly-acrylic acid)/niobium carbide new nanocomposites for sensors. Journal of Biodiversity and Environmental Sciences **13(6).**

Jaleh B, Madad MS, Tabrizi MF, Habibi S, Golbedaghi R, Keymanesh MR. 2011. UV-degradation effect on optical and surface properties of polystyrene-TiO_2nanocomposite film. Journal of the Iranian Chemical Society **8(1),** S161-S168.

Kadhim KJ, Agool IR, Hashim A. 2016. Synthesis of (PVA-PEG-PVP-TiO2) Nanocomposites for Antibacterial Application. Materials Focus **5(5),** https://doi.org/10.1166/mat.2016.1371

Kadhim KJ, Agool IR, Hashim A. 2017. Effect of Zirconium Oxide Nanoparticles on Dielectric Properties of (PVA-PEG-PVP) Blend for Medical Application. Journal of Advanced Physics **6(2).** https://doi.org/10.1166/jap.2017.1313.

Kaur A, Kaur MA, Shahi MN. 2012. How nanotechnology works in medicine. International Journal of Electronics and Computer Science Engineering **1(4),** 2452-2459.

Mirmohseni A, Rastgar M, Olad A. 2019. PANI-chitosan-TiO_2 ternary nanocomposite and its effectiveness on antibacterial and antistatic behavior of epoxy coating. Journal of Applied Polymer Science **136(23).**

Monzillo V, Dalla Valle C, Corbella M, Percivalle E, Sassera D, Scevola D, Marone P. 2014. Antibacterial activity and cytotoxic effect of SIAB-GV3. New Microbiol **37,** 535-41.

Omar MB, Matoussi A. 2012. Dielectric and conductivity investigations of rutile titanium dioxide single crystals. In Electrical Insulation and Dielectric Phenomena **261,** 467-470.

Rashid FL, Hadi A, Al-Garah NH, Hashim A. 2018. Novel Phase Change Materials, MgO Nanoparticles, and Water Based Nanofluids for Thermal Energy Storage and Biomedical Applications. International Journal of Pharmaceutical and Psychopharmacological Research **8(1).**

Ruhal A, Rana JS, Ruhal P, Kumar A, Ruhil M, Ram C. 2013. Antimicrobial nanocomposite of silver and gelatin nanofibers for medical applications. International Journal of Technology Research and Engineering **1,** 177-182.

Singh M, Singh S, Prasad S, Gambhir IS. 2008. Nanotechnology in medicine and antibacterial effect of silver nanoparticles. Digest Journal of Nanomaterials and Biostructures **3(3),** 115-122.

Upadhyay VS, Dubey SK, Singh A, Tripathi S. 2014. Structural, optical and morphological properties of PVA/Fe2O3 nanocomposite thin films. IJCPS **3(43).**

Villatte G, Massard C, Descamps S, Sibaud Y, Forestier C, Awitor KO. 2015. Photoactive TiO_2 antibacterial coating on surgical external fixation pins for clinical application. International Journal of Nanomedicine **10(3367).**