Arabian Journal of Chemistry (2014) 7, 846–855

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

# Synthesis, characterization and antibacterial properties of a novel nanocomposite based on polyaniline/polyvinyl alcohol/Ag

**Mansour Ghaffari-Moghaddam *, Hassan Eslahi**

*Department of Chemistry, Faculty of Science, University of Zabol, Zabol, Iran*

Received 8 September 2013; accepted 16 November 2013
Available online 23 November 2013

**KEYWORDS**

Nanocomposite;
Polyaniline;
Polyvinyl alcohol;
Ag nanoparticles;
Antibacterial properties

**Abstract** In this study, a novel nanocomposite based on polyaniline/polyvinyl alcohol/Ag (PANI/PVA/Ag) has been successfully synthesized. The chemical reduction method was used to produce Ag nanoparticle colloidal solution from $Ag^+$ ions. The polymerization of aniline occurred *in situ* for the preparation of polyaniline (PANI) in the presence of ammonium persulfate. With exposure to Ag nanoparticles on the PANI/PVA composite, a new nanocomposite was obtained. The morphology and particle size of the novel nanocomposite was studied by scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared (FT-IR) analyses. According to XRD analysis, the size of nanoparticles was found to be in the range of 10–17 nm. SEM images showed the favored shape of nanoparticles as triangle which is a benign shape for antibacterial analysis. The antibacterial activity of the obtained nanocomposite was also evaluated against Gram positive bacteria *Staphylococcus aureus* (*Staph. aureus*) and Gram negative *Escherichia coli* (*E. coli*) using the paper disk diffusion method. The antibacterial study showed that the PANI/PVA composite did not have a very good antibacterial activity but PANI/PVA/Ag nanocomposites were found to be effective against two bacteria.


## 1. Introduction

In recent years, the synthesis of nanoparticles has found special attention because of increased surface area to volume ratio, modified structure and increased activity compared to macro molecules (Bardajee et al., 2012; Prashanth et al., 2011; Dror-Ehre et al., 2009). Nanoparticles have many applications in optical, electronic and textile industries, medicine, cosmetic, and drug delivery (Ahmad et al., 2012; Prashanth et al., 2011). The most important nano product in the field of nanotechnology is Ag nanoparticles which are significantly used in textiles and clothing, food packaging, medical and cosmetic ingredients, water, wastewater and air treatment, pesticides and household usage (Honary et al., 2011).

The antibacterial properties of silver have been recognized over 2,000 years ago. In general, Ag nanoparticles are effective

* Corresponding author. Tel.: +98 5422242503.
E-mail address: mansghaffari@uoz.ac.ir (M. Ghaffari-Moghaddam).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

1878-5352 
http://dx.doi.org/10.1016/j.arabjc.2013.11.011

against many bacteria and can destroy 650 types of bacteria, viruses and fungi due to enhancement of antibacterial, antiviruses, and antifungal activity of Ag at the nano scale even around 100%. These nanoparticles are more sustainable, efficient and simple to process when compared with other antibacterial agents (He et al., 2012; Li et al., 2011a; Pourjavadi and Soleyman, 2011; Akhbari et al., 2010; Jones and Hoek, 2010; Mahltig et al., 2009).

There are various methods to prepare nanoparticles. The most important ones are follows: chemical reduction (Lee et al. (2010)), optical reduction (Khanna et al., 2005), hydrogel method (Thomas et al., 2007), sedimentation method (Noritomi et al., 2010), UV and gamma irradiation (Lee et al., 2010), Micelles (Noritomi et al., 2010), and biosynthesis method (Tripathy et al., 2010). Among these methods, the chemical reduction process is the most common industrial method for Ag nanoparticle synthesis. This method has the highest production efficiency and ability for use in a wide range of nanoparticle and nanocomposite production methods (Ahmad et al., 2011).

Nanocomposites are multiphase materials with one of their components between 1 and 100 nm in size. These materials have physical and mechanical properties including high strength, toughness and heat resistance at a wide range of temperature. By mixing various materials and their features, the novel composites with new applications will be produced (Ahmad et al., 2011). Based on the matrix, types of nanocomposites are: polymer nanocomposites, ceramic and metallic nanocomposites, polymer and ceramic or metallic nanocomposites, ceramic–ceramic nanocomposites, metal matrix nanocomposites, thin film nanocomposites, and nanocomposites based on carbon nano tubes (Prucek et al., 2011; Thostenson et al., 2005; Balazsi et al., 2003; Fischer, 2002).

Polymeric nanocomposites are advanced composites obtained from nanoparticles and polymeric matrix which nanoparticles are coated by polymers and a core–shell structure can be formed. Because of the special shape, chemical nature, and unique structure of polymers, nanoparticles can be distributed in a polymer matrix in the best shapes. By coating of nanoparticles and functionalization of particles, the *Van der Waals* forces between nanoparticles are reduced and adaptability and distribution of nanoparticles in the matrix are increased. Polymers are always the first choice for nanoparticle coating. On the other hand, suitable functional groups in polymers structure can be used as reaction sites to control the one-pot synthesis of nanocomposites (Dallas et al., 2011; Jeon and Baek, 2010; Chandra et al., 2008; Wu and Ke, 2007; Guo et al., 2006; Han and Yu, 2006; Shenhar et al., 2005; Chang et al., 2003). In general, nanocomposites based on organic polymers have many advantages such as long-term stability, good process ability, and outstanding optical, catalytic, electronic and magnetic properties. Therefore, the resultant nanocomposites could potentially provide many applications in various areas such as automotive, aerospace, optoelectronics, etc. (Jeon and Baek, 2010). For the synthesis of polymer nanocopmposites, a polymer such as polyvinyl alcohol (PVA), polyvinyl pyrrolidone (PVP), polyethylene glycol (PEG), peroxyacetic acid (PAA), and polyglycolacid (PGA) is needed (Jovanović et al., 2011; Shin et al., 2008).

There are many studies for the synthesis of polymeric nanocomposites in the literature. For example, Bryaskova et al. (2011) synthesized Ag/polyvinylpyrrolidone nanocomposites by thermal or chemical reduction of silver ions to silver nanoparticles. The antimicrobial activities of the synthesized nanocomposites were tested against various bacterial and fungal strains. The results showed a strong antimicrobial property against the tested strains. The polyacrylonitrile/montmorillonite/Ag nanocomposites were also prepared using the chemical reduction of $Ag^{+}$ (*in situ*) by Hwang and Ma (2012). The antibacterial activities of the silver nanoparticle solution, which was obtained by soaking the polyacrylonitrile/montmorillonite/Ag nanocomposite films in distilled water, were tested using the paper disk diffusion method. The results showed that the silver nanoparticle solution was quite effective against tiny bacteria such as *Staphylococcus aureus*, *Escherichia coli* and *Klebsiella pneumonia*.

Polyvinyl alcohol (PVA) has several advantages such as high biocompatibility, biodegradability, hydrophilicity, and ability to form fiber. Because of these features, PVA has a lot of medical applications and is used by virtue of elasticity and tensile strength in some polymers like chitosan. It can be used for coating of Ag (Shin et al., 2008), cellulose (Gea et al., 2010), titanium dioxide (Hebeish et al., 2012), and copper(I) sulfide nanoparticles (Kumar et al., 2002).

Polyaniline (PANI) is another polymer which is also used for coating of Ag (Barkade et al., 2011; Porramezan and Eisazadeh, 2011; Khanna et al., 2005), zeolite (Shyaa et al., 2012), silica gel (Stejskal et al., 2002), and nano fibers, especially gelatin nano fibers (Fan et al., 2012; Li et al., 2006).

The aim of this study is to synthesize a novel nanocomposite based on Ag nanoparticle coating by PANI and PVA polymers. The Ag nanoparticles are prepared using the chemical reduction method, a fast, simple and low cost method. Finally, the antibacterial property of the obtained nanocomposite is evaluated against two pathogenic bacteria, including *Staph. aureus* (Gram positive) and *E. coli* (Gram negative) by using the agar disk diffusion method. To the best of our knowledge, this is the first work on the synthesis of PANI/PVA/Ag nanocomposite by *in situ* polymerization of aniline in the presence of PVA and Ag nanoparticles.

## 2. Materials and methods

### 2.1. Chemicals

All chemicals were purchased from Merck (Darmstadt, Germany). All chemicals were of analytical reagent grade and used without further purification. Silver nitrate ($AgNO_3$) was used as $Ag^{+}$ source and aniline in aniline hydrochloride form was used as monomer for synthesis of polyaniline (PANI).

### 2.2. Microorganisms

The antibacterial activity of prepared nanocoposites was determined using two different bacterial strains including *Staph. aureus* and *E. coli*. All the bacterial strains were obtained from the School of Pharmacy, Medical Science University of Zabol, Zabol, Iran.

### 2.3. Preparation of Ag nanoparticles

Nano sized Ag particles were synthesized by the chemical reduction of $AgNO_3$ using $NaBH_4$ (1:4) in deionized (DI)