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Synthesis of Silver Nanowires Using Solvothermal Method and Its Application as Antimicrobial Agents

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Abstract

Interesting studies on silver nanowires have been conducted in the disciplines of biotechnology and nanotechnology. They are very useful in antibacterial applications because of their conductive and antimicrobial qualities. When silver nanowires are synthesized using the right techniques, they can form nanoscale structures with more surface area, which improves their contact with bacteria and increases their antibacterial efficacy. The aim of this study was to create silver nanowires with ideal solvothermal characteristics and to evaluate the antimicrobial activity. By used ethylene glycol to reduce silver nitrate in polyvinylpyrrolidine at 160^{o}C for 2.5 hours, silver nanowires were successfully produced. The products were examined using SEM, XRD, PSA, and UV-visible spectroscopy. The average size of silver nanowires was 123.0 nm and the highest inhibition zone was 2.33 cm. Overall, the synthesis and use of silver nanowires, with a focus on the solvothermal approach, holds great promise for treating bacterial infections and has a favorable influence on the environment and public health.

Keywords: *antimicrobials, nanoparticle synthesis, silver nanowires, solvothermal method*

1 Introduction

Nanotechnology has brought revolutionary changes in various fields, and one of them is in the development of anti-bacterial materials. One of the materials in the spotlight is silver nanowires. The use of silver nano wires as an anti-bacterial material is interesting because of the unique properties of silver in nano form [1]. Silver has been known for a long time to have antimicrobial properties, and when converted to nano size, these properties are further enhanced [2]. Silver nano particles have the ability to damage bacterial cell membranes and inhibit microbial growth, making them powerful antimicrobial agents [3,4]. Many silver nano synthesis techniques have been reported. The most popular techniques for producing silver nanowires are different chemical processes, namely chemical synthesis [5], hydrothermal method [6], polyol process [7], ultraviolet irradiation photoreduction technique [8], and electrochemical technique [9]. In this paper, we report the successful synthesis of silver nanowires via $FeCl_3$-mediated solvothermal method by reducing silver nitrate ($AgNO_3$) and ethylene glycol (EG) by using polyvinylpyrrolidine (PVP) as adsorption agent. The results of in vitro experiments showed that silver nanowires have antibacterial properties. This compound's ability to inhibit the growth and killing of bacteria has made it a promising candidate in the development of effective antibacterial agents against bacterial infections.

2 Method

2.1 Materials

$AgNO_3$ 99,8% , EG, acetone, 2-propanol, $FeCl_3$, deionized water, Polyvinylpyrrolidone (PVP) supplied by Sigma Aldrich. DMEM media, MEM media, FBS, trypsin 0.25%-EDTA, 1x PBS buffer, Penicillin-streptomycin, Thioglyconate, DMSO.

2.2 Methods

2.2.1 Prepararion silver nanowires

Silver nanowires were prepared by reducing $AgNO_3$ and EG before PVP [10]. When 0.15M PVP was added, the force was enhanced by an EG solution containing 10 ml of 0.1 mM $FeCl_3$. Using a syringe and 10 ml of magnetically stimulated EG $AgNO_3$ solution (0.1 M), the combined solution is added drop by drop. The mixture has turned into a milk white. After that, a 25 ml bottle is filled with the solution. Teflon walled autoclave tube. This tube should not be closed. It is kept at 160 °C for 2.5 hours before being allowed to naturally cool to 25 °C. After a significant amount of acet-is added, simple silver nanowires were isolated from EG by centrifugation and sonication. After then, it is scattered in ethanol to allow for additional identification.

2.2.2 Silver nanowires characterization

Silver nanowires characterization used a FESEM Thermos Scientific Quattro S equipped with an EDS detector, WetSTEM, heating stage, and tensile stage was determined morphology. The phase structure was found through X-ray diffraction (XRD). Particle size analyzer (PSA) (Horiba Nano Partica SZ-100) using a dynamic light scattering (DLS) method with a non-invasive backscattering (NIBS) technique using a 4 mW HeNe laser Particle size distribution was measured and Nanoparticle zeta potential (Horiba Nano Partica SZ-100) is frequently used to describe nanoparticles' surface charge properties and UV-Vis (1800 Shimadzu, Kyoto, Japan) in the 200-800 cm^{-1} region.

2.2.3 Antimicrobial activity test

The antimicrobial test adopts the well diffusion method. on a double-layer test medium. As the bottom layer, for bacteria, Mueller-Hinton agar (MHA) medium or Sabouraud dextrose agar (SDA) for yeasts and molds were used an agar concentration of 16 g/L each, while as the top layer, the same medium was used with agar concentration - agar each of 8 g/L. The test bacteria were grown on Mueller Hinton Broth (MHB) media and incubated at a temperature of $\pm 25^0$C in a shaking incubator for 24 hours. Yeast was grown on *Sabouraud Dextrose Broth* (SDB) media and incubated at ±25°C in a shaking incubator for 24 hours. Molds were grown on Sabouraud Dextrose Agar (SDA) media and incubated for five days at 25°C for the test microbes or until spores were produced. The test microbial culture was then diluted to 105 CFU/mL for yeast and 106 CFU/mL for bacteria, and 104 CFU/mL for mold spores using semi-solid MHA (bacteria) or SDA (yeast and mold) growth media as a coating which is then poured over the bottom layer media. After the top layer of the medium containing the test microbes had solidified, the wells were 0.5 cm in size. Samples in (Table 1) are inserted into the wells in the test medium as much as 50 µl . As a control, sterile distilled water was used. This test medium was then incubated at 4°C for 1 hour and then continued to be incubated at 30°C. The test was carried out with three replications. The inhibition zone formed was calculated on day 2.

3 Result and Discussion

3.1 Silver nanowires characterization

The synthesis of silver nanowires has been carried out successfully, as supported by experimental data. The SEM characterization results in Figure 1, show that the silver nanowires produced have a consistent nanometer in diameter and a regular structure with a homogeneous although not completely uniform surface. The morphology of the silver nanowires is characterized by pentagonal crystal shape along the nanowires [11,12].

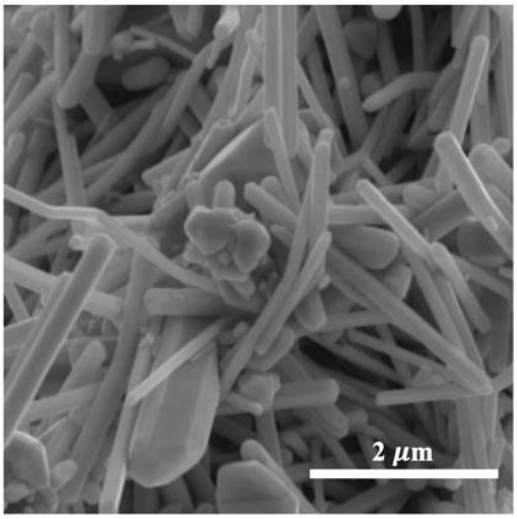

Figure 1. FESEM images of obtained silver nanowires

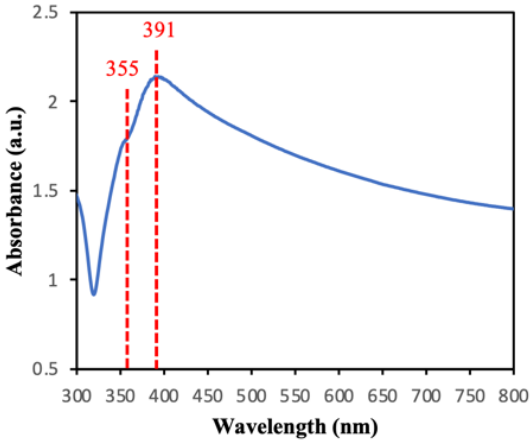

Figure 2. The UV–Visible of Silver nanowires

Also, we recorded the spectrum of silver nanowires by UV-Vis spectroscopy, as shown in Figure 2. UV-Vis spectroscopy is a convenient method to determine the size and shape of silver nanowires structures because of the different resonance nodes at different wavelengths. This figure shows an absorption band with a peak at 391 nm and a shoulder at 355 nm, indicating the formation of silver nanowires [13].

Furthermore, the analysis of the synthesized XRD (X-ray diffraction) data of silver nanowires showed the crystal structure of face centered cubic (FCC) (JCPDS database) (04-0783) [14]. Silver nanowires at 38.2°, 44.48°, 64.74°, and 77.76° corresponding to (111), (200), (220), and (311), respectively as shown in Figure 3. Silver nanowires are well integrated, as shown by the relationship between the four crystal peaks in the FCC structure of silver nanowires, which has a cubic structure based on (111) as the peak of silver nanowires [15,16].

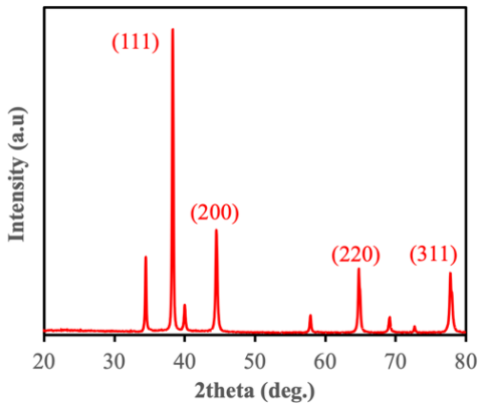

Figure 3. XRD patterns of silver nanowires

Table 1. Test microbes and samples used in the test

Material (Microbe/Matrix)		Code
Gram Positive Bacteria	*Bacillus subtilis* InaCC B1	BS
	Staphylococcus aureus InaCC B4	SA
Gram Negative Bacteria	*Eschericia coli* InaCC B5	EC
	Pseudomonas aeruginosa InaCC B3	PA
Yeast	*Candida Albicans* InaCC Y116	CA
Mold (Filamentous Fungi)	*Aspergillus flavus* InaCC F44	AF
Silver Nanowires	1000 ppm	F1
	500 ppm	F2
	250 ppm	F3
	125 ppm	F4
	62.5 ppm	F5
	31.25 ppm	F6
	15.63 ppm	F7
	7.81 ppm	F8
	3.91 ppm	F9
	1.95 ppm	F10
Negative Control	Aquades or distilled water	K

Table 2. Test results of the sample's ability to inhibit the test microbe after incubation for 2 days

Sample	Code	Average of test microbial inhibition zone (cm)					
		SA	BS	PA	EC	CA	AF
Ag NWs	F1	2.33	0.68	1.05	0.88	0.55	0.05
	F2	2.38	0.68	1.08	0.93	0.47	0.25
	F3	2.58	0.69	1.13	0.97	0.46	0.20
	F4	2.57	0.75	1.03	1.05	0.50	0.20
	F5	2.45	0.74	0.98	0.95	0.30	0.15
	F6	1.58	0.59	1.03	0.78	0.00	0.00
	F7	1.30	0.45	0.88	0.61	0.00	0.00
	F8	0.88	0.30	0.58	0.45	0.00	0.00
	F9	0.65	0.10	0.36	0.31	0.00	0.00
	F10	0.42	0.05	0.30	0.31	0.00	0.00

In this study, we also measured the particle size distribution (PSA) of silver nanowires using the dynamic light scattering (DLS) method. The measurement results show that 27% of the particles have a size of about 202.1 ± 14.5 nm, while the remaining 73% have a size of about

1125.1 ± 123.0 nm, which are all within the nanometer size range. The polydispersity index of 0.56 found in this study indicates a high degree of stability of the silver nanowires produced. These results also indicate that the silver nanowires have properties that are suitable for the desired applications. The stability of silver nanowires achieved in this study can be attributed to the role of PVP (Polyvinyl Pyrrolidone) as a stabilizer in the synthesis of silver nanowires [15].

3.2. Antimicrobial activity of silver nanowires

Based on the results of the MIC test on the sample (Table 1), it was known that the silver nanowires material had Ability to inhibit test growth microbes (Figure 4). The negative control in the form of distilled water did not show an inhibition zone. The results of the large inhibition zone measurements are presented in Table 2.

The study of antimicrobial activity found that silver nanowires are more effective in inhibiting gram-positive Staphylococcus aureus than gram-negative bacteria, which is consistent with the results of the study [17]. Numerous researchers have tested the antimicrobial efficacy of silver nanowires against a wide variety of bacteria, fungi, and viruses, including MDR and non-MDR strains. It has now been established that metal particles in the nanoscale are promising alternatives to antibiotic therapy because they have tremendous potential to solve problems associated with the development of multidrug resistance to pathogenic microorganisms. Hence, they are also considered next-generation antibiotics [18]. Based on these findings, it can be concluded that silver nanowires have potent antibacterial activity by involving several mechanisms, including adhesion to cell membranes [19], damage to intracellular components [20], production of free radicals and reactive oxygen species [21], modulation of the human cell immune system [22]. Silver nanowires are effective in suppressing microbial growth, making them a potential agent in the treatment of bacterial problems

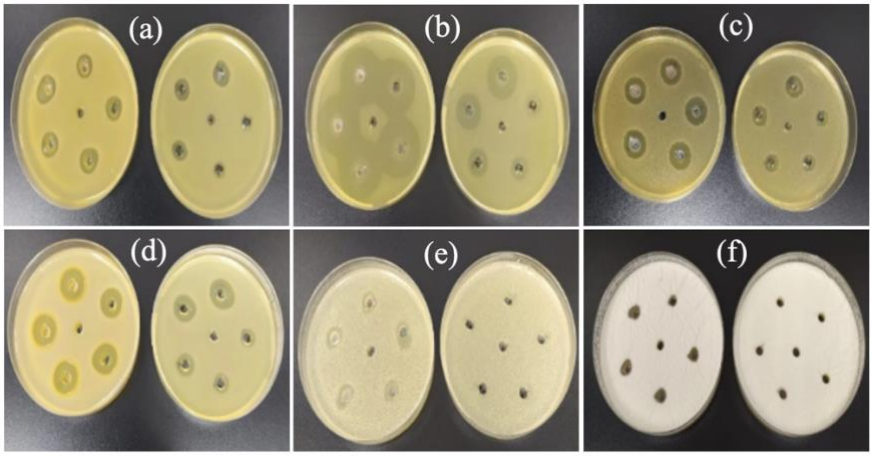

Figure 4. The ability of silver nanowires to inhibit the growth of (a) BS; (b) SA; (c) PA; (d) EC; (e) CA; and (f) AF which was incubated for 2 days at 30^{o}C while the negative control well in the form of distilled water was placed in the center of the test dish

4 Conclusion

Silver nanowires have been successfully synthesized by solvothermal method, also showed absorption peak at 391 nm and shoulder at 355 nm indicating the formation of silver nanowires and anti-microbial test results using the MIC method showed potential results as antimicrobials.

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