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Eco-friendly production of silver nanoparticles with crocus plant extract: Properties and antimicrobial efficacy

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Abstract

In this investigation, we focus at how AgNPs can improve the efficiency of antimicrobial treatment. In this study, silver nanoparticles were produced using a "green synthesis" approach that used Silver nitrate solution was stirred by magnetic stirrer at 60C and the Crocus plant (AgNPs). Based on their investigations into produced nanoparticles of AgNPs, and their optical, structural, and topographical characteristics, the researchers have concluded that the AgNPs thin film is poly-crystalline and has numerous peaks. Crystallite sizes in the film were calculated using Scherrer's method. Antibacterial efficacy was evaluated by the disk method on two distinct microorganisms. The identified inhibitory zones prove that the as-synthesized AgNPs are an effective antibacterial agent against dangerous bacteria and other pathogens.

Keywords: Silver nanoparticles synthesized, green synthesis, antibacterial activity thin film

1. Introduction

Applications for Nanoparticles (NPs) may be broken down into many subcategories because of their unique combination of chemical and physical properties. The production of NPs has become a topic of concern as a result of the fact that both the chemical processes and the physical processes involved are hazardous (toxic). As a consequence of this, people all over the world felt the need for a different alternative in the production of nanoparticles, which ultimately led to the development of green nanotechnology (or environmentally friendly NANO biotechnology). The term "green nanotechnology" refers to the use of biological processes in general, such as the production of Nanoparticles (NPs) by organisms such as plants, bacteria, and fungus ^[1-3]. The fact that plant extracts are readily available, safe, non-toxic, and kind to the environment are among the key benefits associated with the synthesis of AgNPs utilizing plant materials. Conductivity in AgNPs is of the n-type, and its energy gap is rather substantial 3.3 and 2.2 eV. This material is distinguished by its ionic structure, low electrical resistance, and high transmission in a visible region of the solar spectrum. The most well-known uses of silver nanoparticles (AgNPs) are optoelectronics, phototransistor photodiodes, and photovoltaics. AgNPs also cleared the door for novel approaches to the elimination of cancer cells and the administration of drugs ^[4]. AgNPs NPs have exceptional antibacterial efficacy against a wide variety of antibiotic-resistant pathogenic microorganisms ^[5, 6].

2. Experimental part

To begin the process of preparation, AgNO₃ from Sigma (169.873 g/mol) was combined with 0.169 gm of AgNO₃, which was then dissolved in 1 liter of pure water at room temperature. The solution was then agitated for 15 minutes to ensure that it was completely mixed. A dark container is used to store the solution in order to prevent was completely mixed. A dark container is used to store the solution in order to prevent oxidation and mixing.

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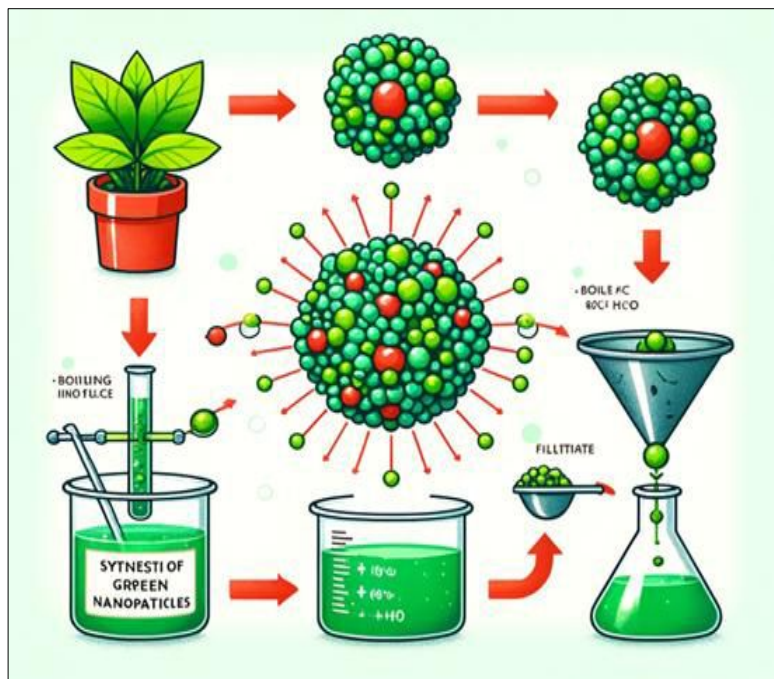


Fig 1: Synthesis of green nanoparticles

Crocus plant (1 g) was heated at 50 degrees Celsius for 30 minutes in 100 milliliters of deionized water. In order to remove any solid particles, the resultant solution was filtered using paper. After the filtering step, after adding the crocus solution to the cadmium acetate solution, stir the mixture for a certain amount of time to ensure a uniform mixture, and then cool the solution to room temperature. The needed material is constructed from the top using a specialized syringe, and the drop-casting process is utilized to cast the material onto the glass substrate once the material has been dropped from the syringe. The first step in the process involves placing one drop at a predetermined location on the glass sample using a syringe. Once this is done, the sample is dried at a specific temperature for a predetermined amount of time (10min). After heating the substrate to dry for 10 minutes, we added a second drop of the same amount right on top of the first. After that, we saw that the film had changed hue, which is a telltale sign that

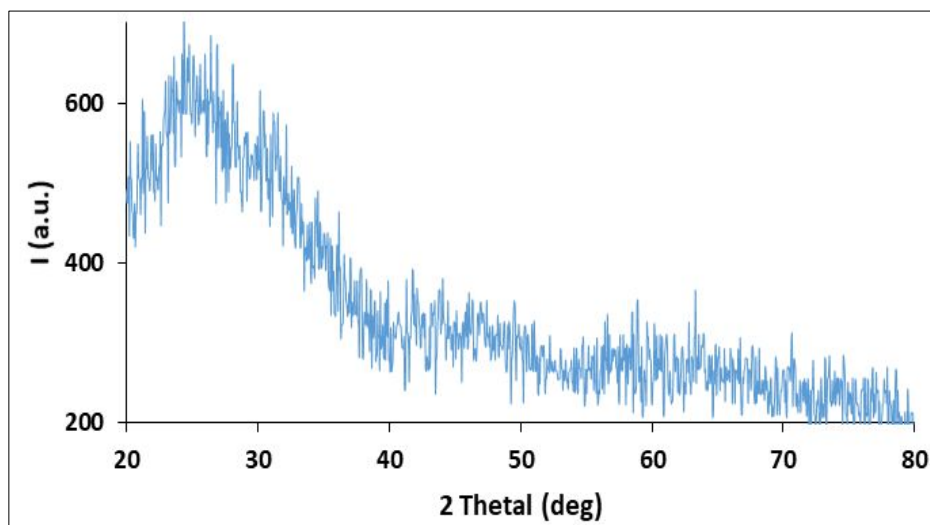
we had really acquired a film with AgNPs embedded inside it. We employed X-ray diffraction to ensure that the substance we got did, in fact, contain AgNPs.

3. Results and Dissection

3.1 XRD analysis

Figure 1 demonstrates X-ray Diffraction (XRD) patterns of drop-cast AgNPs on glass substrates. After the film was synthesized using a method that didn't harm the surrounding ecosystem, it was deposited. Peaks in the AgNPs film matched those in the standard X-ray pattern file (ICDD card No. 801916, JCPDS file No. 039-1221) for the (111), (111), (210), (211), and (400) planes [7]. The crystal size may be calculated using the Debye-Scherrer equation given in [7, 8].

$$C.S = \frac{0.94\lambda}{FWHM \cos \theta} \quad (1)$$



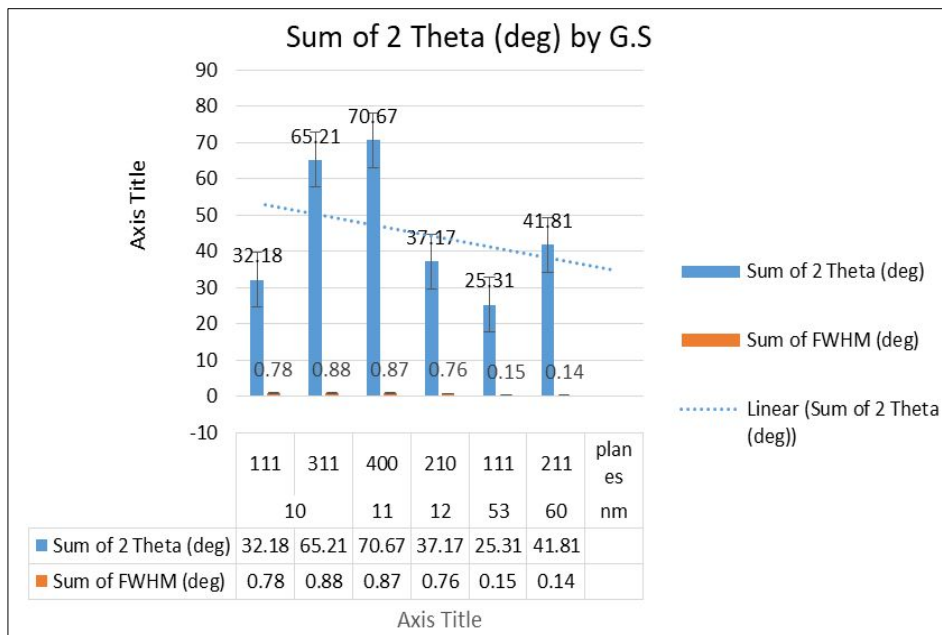


Fig 2: XRD pattern of Ag NP s as a thin film

Table 1: Summary of XRD parameters

2 Theta (deg)	FWHM (deg)	Hkl planes	G.S nm
25.31	0.15	111	53
32.18	0.78	111	10
37.17	0.76	210	12
41.81	0.14	211	60
65.21	0.88	311	10
70.67	0.87	400	11

3.2 AgNPs thin film's surface microstructural characteristics

Material microstructure study is a typical application of Scanning Electron Microscopy (SEM). Figure 3 showed that the images of AgNPs NPs applied to a substrate by drop casting were distinct and well-defined. The thin film AgNPs are composed of evenly distributed, spherically formed grains with a tiny amount of irregularly shaped patches. Their approximate average particle size is 74.13 nm.

Result of the included optical band data, the UV-Vis spectrum is given top priority. As can be seen in Figure (4), the AgNPs thin film's optical transmission was only around 15% when tested at a wavelength of 200 nm, but it increased considerably to 90% when measured at a wavelength of 900

nm. The influence of quantum size can be responsible for both the high transmittance exhibited by the AgNPs film and the blue shift of the absorption edge ^[9]. This effect happens as particles get smaller and widens the energy gap as a result. The Tauc equation was used to get the parameters for the optical energy gap (E_g) of the AgNPs film.

The direct band difference ($h\nu$) can be measured using the $(\alpha h\nu)^2$ vs. photon energy graph. By extending the line until it reaches the point where $(\alpha h\nu)^2 = 0$, one can determine the band gap. As seen in Figure 4, the quantum size influence causes the energy gap to expand by 5.5 eV in comparison to bulk thin film ^[10, 11].

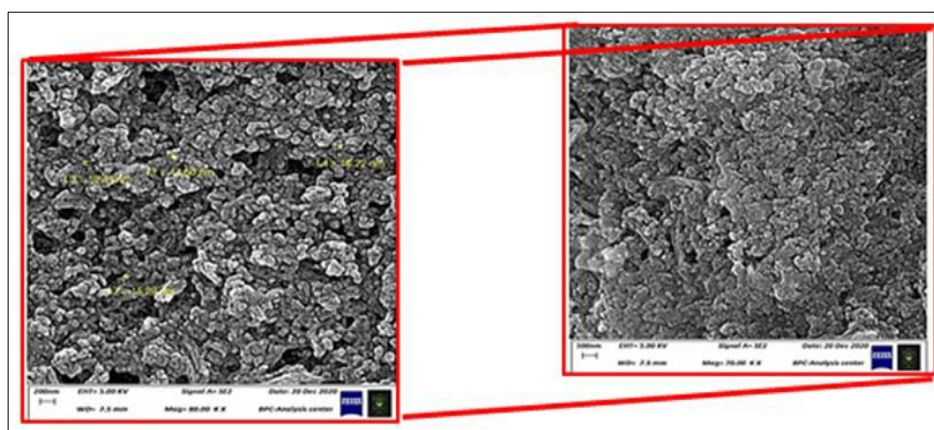


Fig 3: SEM analysis of Ag NPS by drop casting

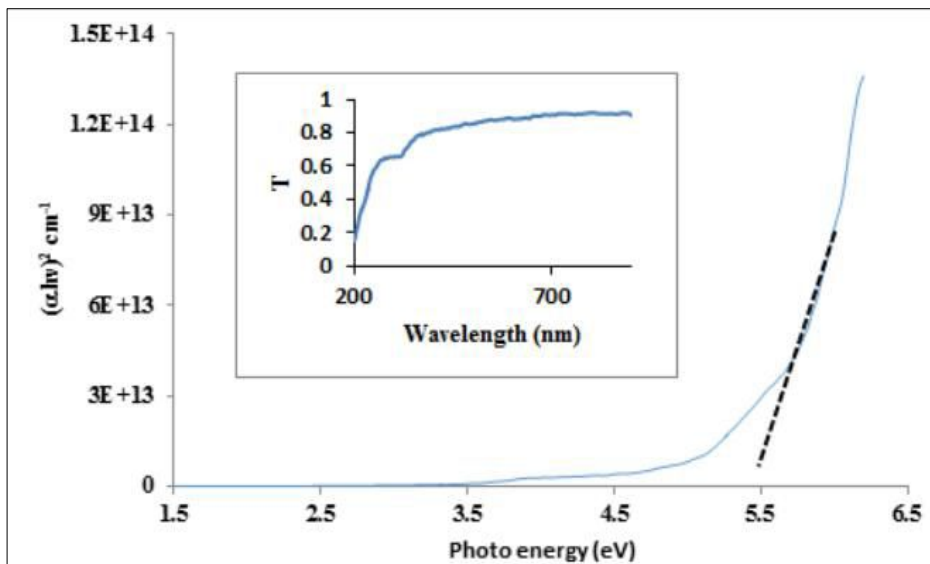


Fig 4: Transmittance Spectra and $(\alpha h\nu)^2$ versus photon energy gap of prepared thin films

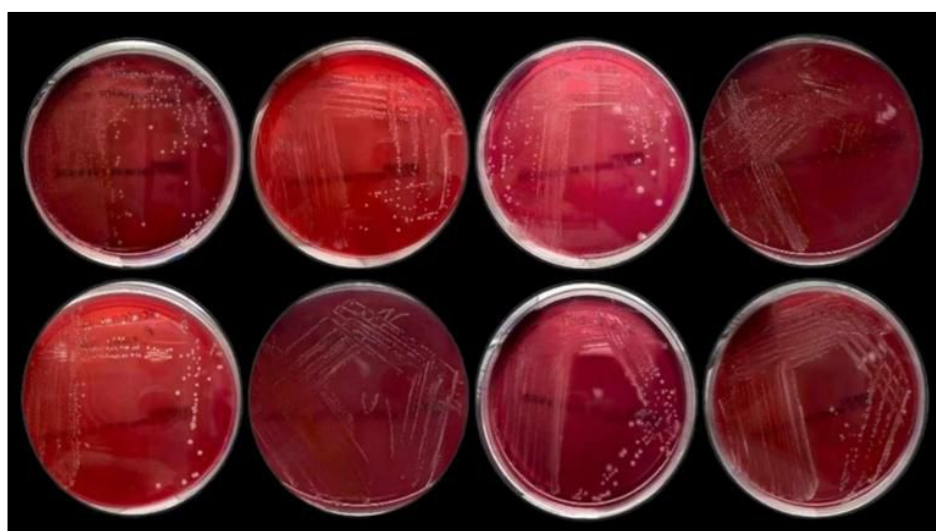


Fig 5: Ag NPs' antimicrobial properties against *Staphylococcus aureus* and *E. coli*.

3.3 Antimicrobial activity

When *E. coli* and *Staphylococcus aureus* strains were cultured at 37 degrees Celsius for twenty four hours, the antibacterial properties of silver Nanoparticles (NPs) were investigated using the disk technique of diffusion in agar wells. Figure 5 depicts this. As can be shown in Table 2, the antibacterial activities of the AgNPs have been demonstrated to be quite effective against harmful microorganisms.

Table 2: activity against germs

Compound (control 6mm)	<i>Staphylococcus aureus</i>	<i>E. Coli</i>
6 mm	30 mm	29 mm

Potential variables affecting the efficacy of AgNPs' antibacterial action include: Significant aspects in the actions that take place, such as Reactive Oxygen Species (ROS) formation, cadmium⁺² ion release, and the size and shape of the produced AgNPs. Due to DNA, membrane, and protein damage, bacteria die when Reactive Oxygen Species (ROS) are generated and certain species are allowed to pass past the membranes of their cells. In the presence of water, the samples release Ag⁺¹ ions, which are taken up by bacteria through a transport system once they reach the cells. As can be observed in Fig. 6, due to intense electrostatic contact with a negatively charged cell layer, this causes the bacterium to die [12-15].

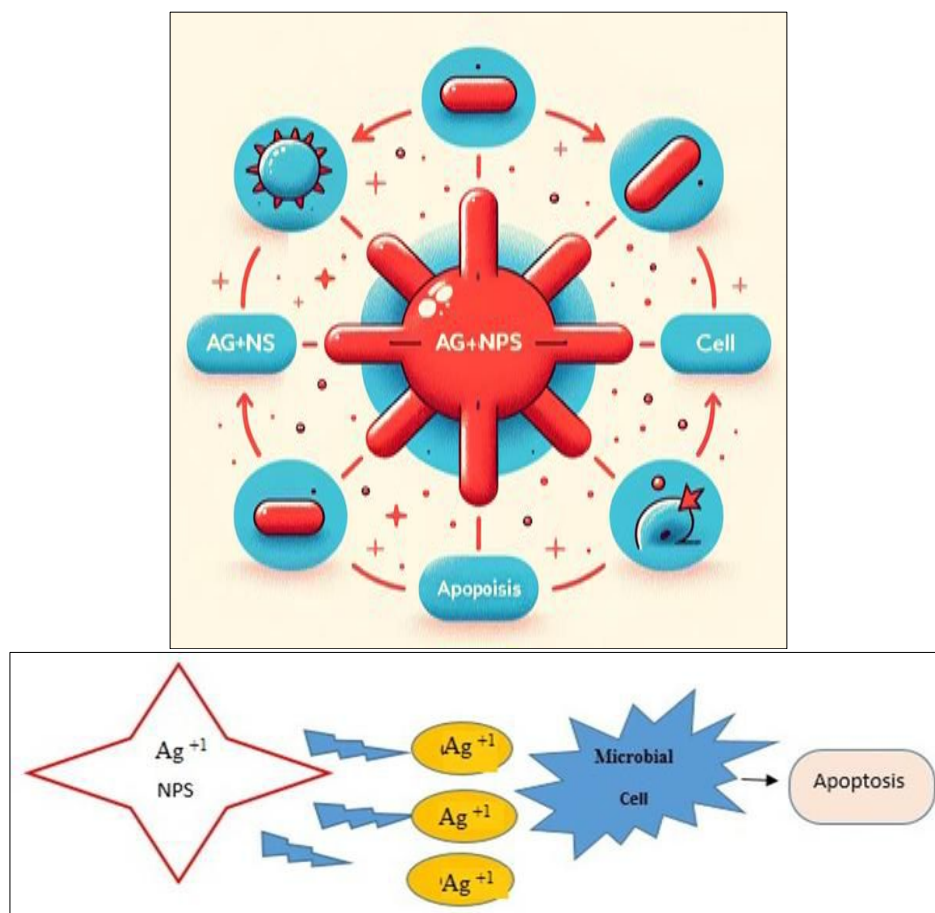


Fig 6: A bacterial cell membrane is negatively charged, which is why bacteria are so susceptible to electrolysis

4. Conclusions

The production of silver nanoparticles utilizing a green chemistry process that involved the aqueous extract of leaf material was shown to be risk-free, uncomplicated, and an effective strategy. Producing silver nanoparticles (Ag NPs), characterizing them, and discussing their antibacterial characteristics are all included in this study. X-ray powder diffraction analysis confirmed its polycrystalline nature. Antimicrobial experiments were performed on a large panel of pathogenic bacteria to determine the effectiveness of NPs as an antibacterial agent. The observed zone of inhibition demonstrates that Ag NPs are effective at inhibiting bacterial growth.

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