

RESEARCH PAPER

## Novel Sustainable Synthesis of Small-Sized Zero-Valent Gold Nanoparticles via Photo-Irradiation Method: Follow-Up on Synthesis with Different Irradiation Periods

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### ARTICLE INFO

#### Article History:

Received 05 December 2025

Accepted 04 February 2026

Published 01 April 2026

#### Keywords:

Gold nanoparticles

Photo-irradiation

Sustainable synthesis

### ABSTRACT

Green nanotechnology has advanced significantly with the development of new, eco-friendly zero-valent gold nanoparticles (AuNPs) by photo-irradiation. This innovative technique converts gold ions into zero-valent nanoparticles using photo-irradiation method. This synthesis accomplishes a more sustainable, cost-effective, and strength-green way by using eco-friendly components and utilizing solar or LED light resources. The photo-irradiation technique entails the excitation of a mild-touchy agent, inclusive of a natural photosensitizer, which helps the discount of gold ions in the presence of water or aqueous answers. This technique offers manipulation over nanoparticle length, shape, and distribution, making it suitable for an extensive variety of applications, together with drug delivery, catalysis, and sensors. The preparation of nano-gold has been followed by different irradiation periods. Using X-ray diffraction (XRD) to look at the gold NPs) revealed that they were shaped like a face-centered cubic, with 15.63 nm of space between the crystal faces and a lattice parameter that ranged from 1.225 to 2.342 Å. Using energy dispersive X-ray spectroscopy (EDX) to look at the finished products showed that they only contained elemental gold (Au), which proved that the material was pure. The EDX mapping of the particles demonstrated a remarkable dispersion of metallic gold. We looked at the nano-synthesized products' shape, optical properties, and particle size using transmission electron microscopy (TEM), UV-visible absorption, and scanning electron microscopy (SEM). The Au nanoparticles' particle diameter was found to be between 18 to 32 nm.

### How to cite this article

Mohammed M., Al-Rubaei S., Rheima A., Al-Kazazz F. Novel Sustainable Synthesis of Small-Sized Zero-Valent Gold Nanoparticles via Photo-Irradiation Method: Follow-Up on Synthesis with Different Irradiation Periods. J Nanostruct, 2026; 16(2):2070-2077. DOI: 10.22052/JNS.2026.02.053

### INTRODUCTION

Gold has been prized for its beauty and software for millennia, however latest improvements in nanotechnology have opened new frontiers for this precious steel [1]. Nano gold, or gold nanoparticles (AuNPs), are gold debris with

dimensions starting from 1 to one hundred nanometers [2, 3]. These tiny particles exhibit precise bodily, chemical, and organic homes due to their length and huge floor-to-volume ratio [4]. This versatility has spurred extensive studies into their programs across numerous fields, which

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includes medication, industry, and environmental science [5]. This article offers a comprehensive evaluation of these packages, highlighting the transformative potential of nano gold in each area. Nano gold has revolutionized scientific diagnostics by permitting especially sensitive detection of biomarkers and pathogens [6]. Gold nanoparticles are typically utilized in lateral flow assays (LFAs), a technology widely employed in domestic pregnancy checks and ailment detection kits [7, 8]. For instance, the binding of gold nanoparticles to precise antibodies or antigens consequences in a colorimetric alternate that can be effortlessly visualized, making an allowance for rapid and accurate diagnostic outcomes [9-11]. In imaging techniques, nano gold enhances the assessment of imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) [12, 13]. Gold nanoparticles improve the assessment in CT scans due to their excessive atomic range, which increases X-ray attenuation [14-16]. Additionally, gold nanoparticles can be engineered to target tissues or cells, imparting designated pics of pathological adjustments [17]. It's hired in centered drug transport systems, supplying precision in therapeutic interventions [18, 19].

By conjugating pills with gold nanoparticles, researchers can make sure that the medicine is delivered immediately to the diseased cells, minimizing aspect outcomes and improving efficacy [20, 21]. This approach is mainly promising in cancer remedy, in which gold nanoparticles can goal and wreck tumor cells with minimal effect on surrounding wholesome tissue [22].

One of the maximum thrilling packages of nano gold in remedy is photothermal therapy [23, 24]. Gold nanoparticles soak up close to-infrared (NIR) light and convert it into localized warmth [25, 26]. This warmth can selectively damage most cancers cells at the same time as sparing healthy tissue, making it an effective device in most cancers' remedy [27]. The potential to precisely manipulate the heating manner via NIR irradiation permits for targeted remedy and advanced treatment effects [28, 29].

In the sphere of power garage, nano gold contributes to the development of superior batteries and supercapacitors [30]. Gold nanoparticles enhance the overall performance of strength garage devices with the resource of improving price storage ability and conductivity [31, 32]. These improvements can result in extra

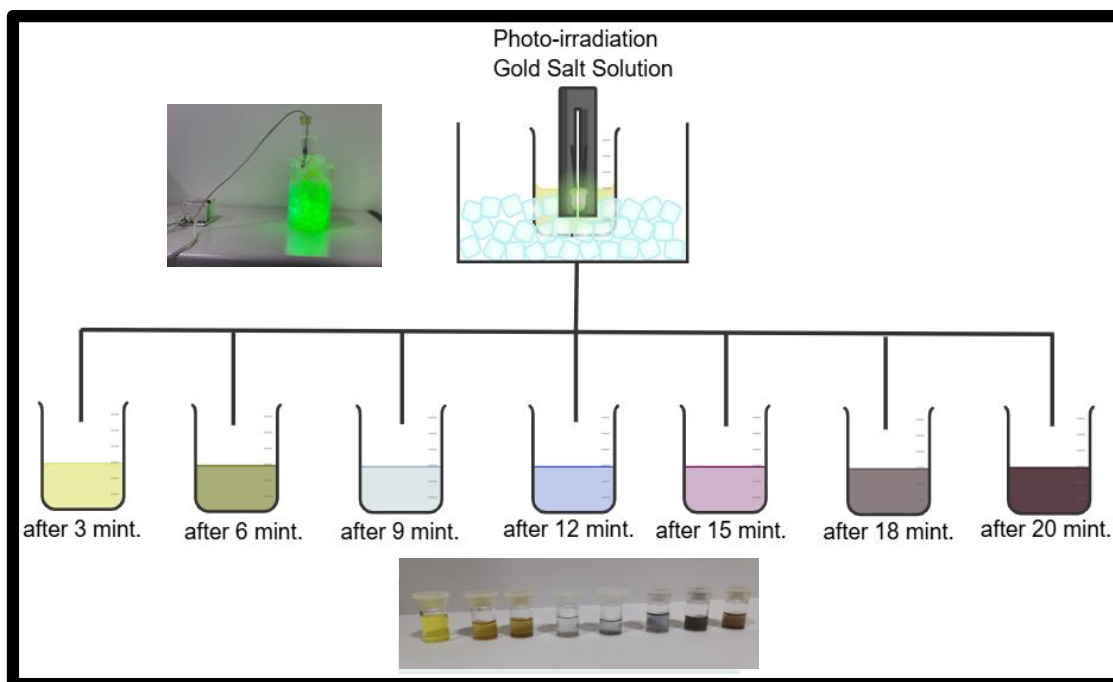


Fig. 1. Schematic illustration of the synthesis of zero-valent AuNPs via photo-irradiation technique.

green and sturdy electricity garage solutions for diverse packages, which include electric motors and renewable electricity structures [30]. The houses of nano gold make it a useful fabric throughout a huge variety of programs [33-36]. In medicine, it complements diagnostic accuracy, recuperation efficacy, and imaging skills [37, 38]. In employer, it drives upgrades in catalysis, electronics, and material technology. In the environmental era, it gives innovative solutions for water purification, sensing, and soil remediation. Furthermore, its programs make cosmetics and energy garages bigger, showcasing its versatility and capability for destiny enhancements [39]. As studies and era continue to evolve, the placement of nano gold is probably to amplify, presenting new opportunities and solutions throughout numerous domains. Its integration into diverse fields underscores the transformative impact of nanotechnology and highlights the importance of persisted exploration and development on this location [40-42]. Photoirradiation generation gives several benefits within the steerage of nanomaterials, which includes progressed control over particle size and morphology, sustainable synthesis, real-time

tracking, versatility, facilitation of complicated nanostructure formation, and selective synthesis [43, 44]. These blessings make photoirradiation an appealing and powerful technique for nanomaterial synthesis, aligning with modern developments toward inexperienced chemistry and precision engineering [45]. As research continues to increase, the software of photoirradiation era in nanomaterial steering is anticipated to expand, using innovation and development in numerous scientific and commercial fields. The capability to harness light for particular and managed synthesis opens new possibilities for the introduction of advanced nanomaterials with tailored houses and functionalities [46].

The goal of this has a look at is to prepare gold nanoparticles with the aid of photoirradiation with special irradiation instances. This method becomes used due to the fact its fee is low, and waste is reduced, as well as the quick education time and splendid nanostructure.

#### MATERIALS AND METHODS

##### *Novel Synthesis Zero-Valent Gold Nanoparticles*

The UV irradiation method was used, which

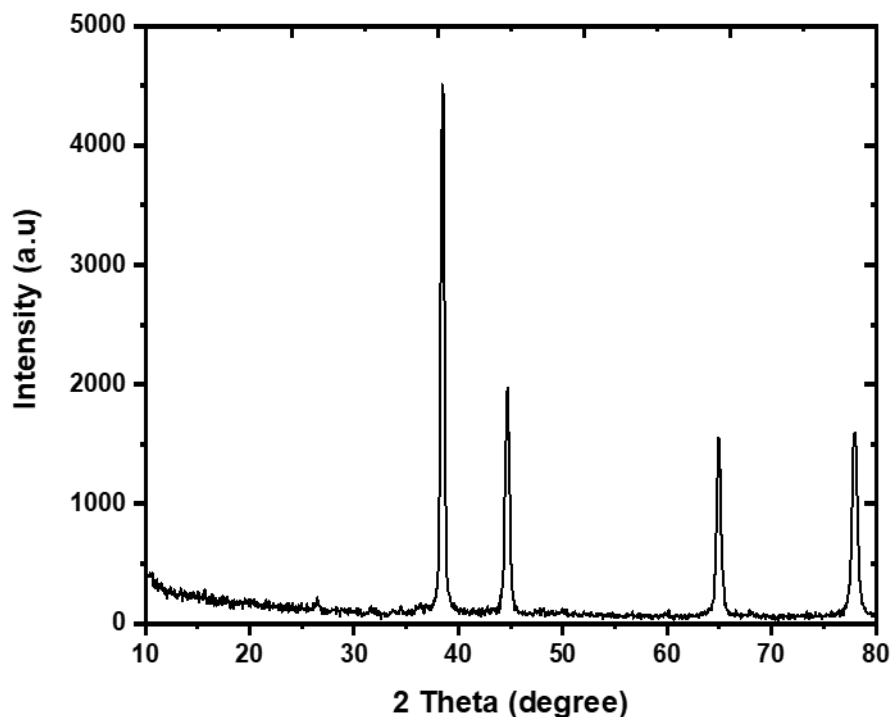


Fig. 2. XRD pattern of the synthesized AuNPs by photo-irradiation method.

is a sustainable and newly designed method for the synthesis of non-valent gold nanoparticles. As shown in the Fig. 1, a mercury lamp was used as a source of UV radiation with a wavelength of 365 nm and a power of 125 W. Cooling was achieved using an ice bath used to reduce the temperature of the photoreaction, and the reaction tank containing the irradiation cell was immersed inside it. A 0.02 mol ( $\text{AuHCl}_4$ ) gold solution with a volume of 50 ml was irradiated with different irradiation periods (3-20 min). A visible color change from yellow to dark pink was observed in the gold solution, indicating the formation of Au<sup>0</sup> resulting from the reduction of Au<sup>+3</sup>. After the irradiation process was completed, the solution was washed with deionized water several times, and then the solution was dried at room temperature.

## RESULTS AND DISCUSSION

### Characterization of gold NPs

#### X-Ray Diffraction (XRD) analysis

The sample was examined by X-ray diffraction, measured by the SHIMADZU XRD-6000 device at a  $2\theta$  range of  $10^\circ$ - $80^\circ$ . The pattern of the zero-valent gold nanoparticles is shown in Fig. 2.

The photoluminescence method confirms the new creation of zero-valent gold nanoparticles crystallized by the peak function  $2\theta$  of the preferred gold nanoparticles. The XRD analysis verifies that the gold nanoparticles own a face-targeted cubic (fcc) crystal shape, regular with the JCPDS reference sample No. 00-004-0784. When looking at the figure, four peaks at  $2\theta$  are found, which are  $38.519^\circ$ ,  $44.675^\circ$ ,  $64.976^\circ$ , and  $77.875^\circ$ , which correspond to the (111), (200), (220), and (311) planes of cubic gold. The moving edge period of the cubic unit is  $4.0095 \text{ \AA}$ . The d-spacing values similar to the (111), (220), (two hundred), and (311) crystallographic planes have been calculated to be  $2.337 \text{ \AA}$ ,  $2.028 \text{ \AA}$ ,  $1.435 \text{ \AA}$ , and  $1.226 \text{ \AA}$ , respectively. The Debye-Scherrer equation estimates the crystalline length of Au nanoparticles to be 20.19 nm.

### UV-Vis absorption

Fig. 3 displays the UV-Vis absorption spectra of photoreduced, solid zero-valent gold nanoparticles, highlighting their optical characteristics. The look of a sturdy absorbance height at 548 nm is indicative of a success synthesis

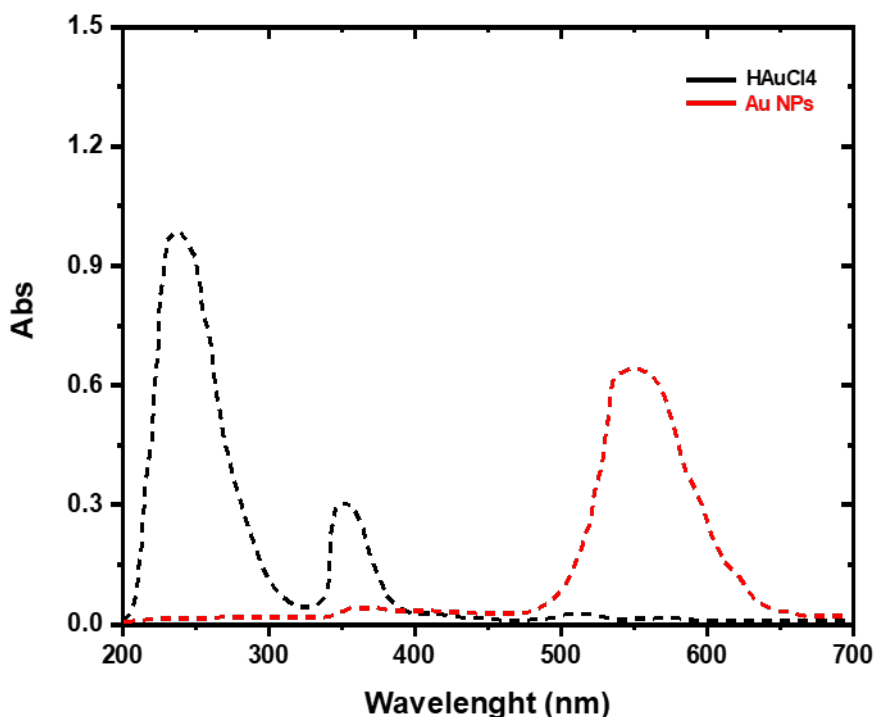


Fig. 3. UV-Vis Spectro Photo-irradiation Zero-valence Au NPs.

of gold nanoparticles. The height indicates a little blue shift resulting from a reduction in particle size, perhaps due to confinement effects. This transition denotes the decrease of gold from Au(III) to Au(0) in the photograph. The observed spectral shift confirms that the progressive and eco-friendly photolysis approach hired on this examine correctly facilitated the fast, unmarried-step discount of gold salts into gold nanoparticles.

*Scanning Electron Microscope (SEM) analyze*

The FE-SEM is a suitable technique for surface morphology analysis. FE-SEM was used

to study the morphology of gold nanoparticles, determining the size, shape, and distribution of the nanoparticles. Fig. 4a shows the scanning electron microscope (SEM) image of the gold nanoparticles produced by photoirradiation. Fig. 4a shows that the gold nanoparticles produced by photoirradiation have a spherical shape, with positive clusters. The surface plasmon resonance (SPR) peak of gold nanoparticles synthesized via the novel photolysis method was thoroughly examined in the UV-Vis spectrum (Fig.4, purple line). The particle sizes were found to be between 24 and 33 nm on average. This novel synthesis

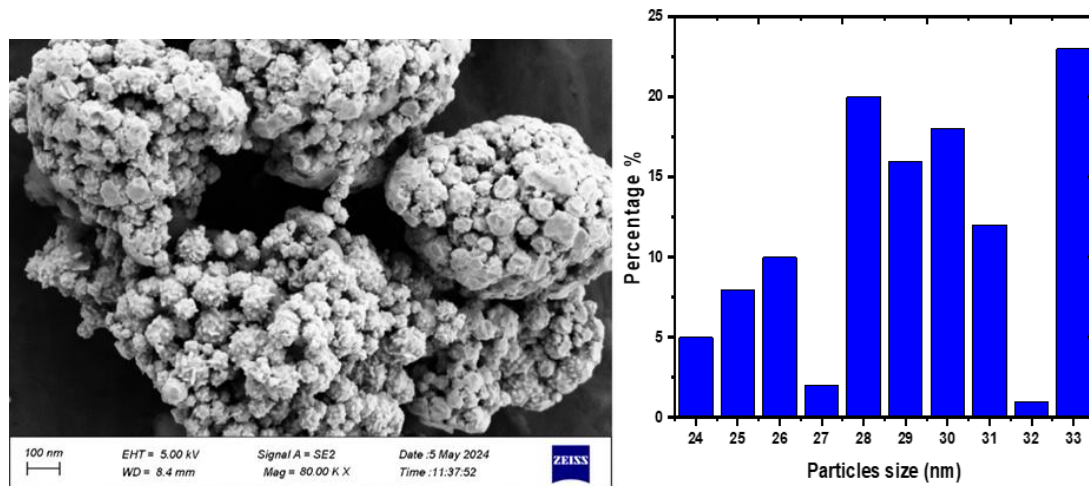


Fig. 4. (A) FE-SEM image and, (B) particle-size distribution histogram of AuNPs produce by photo-irradiation process.

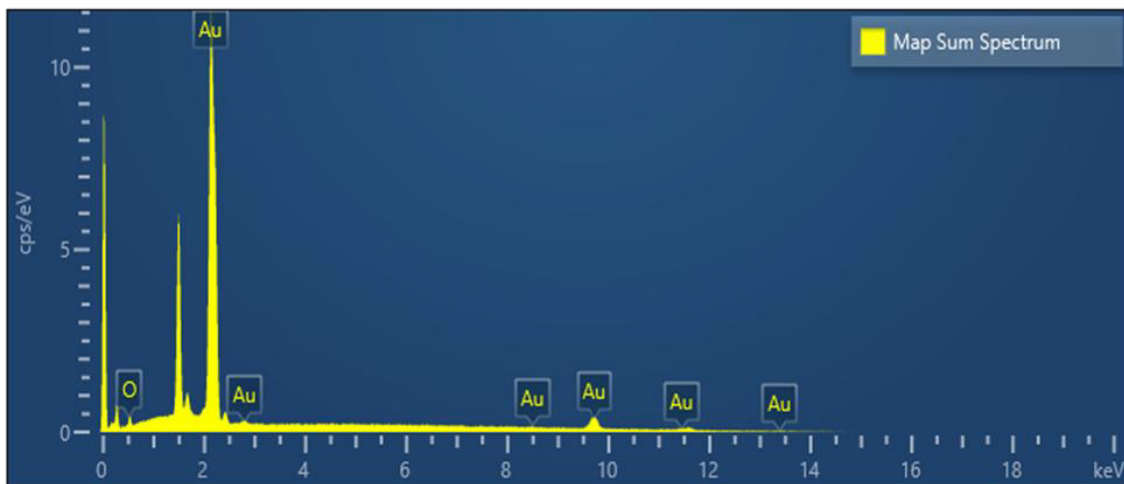


Fig. 5. EDX spectrum of Zero-valence AuNPs prepared in this work.

method for gold nanoparticles was found to be advantageous, yielding smaller particle sizes with a narrower size distribution. The nanoparticle size distribution was analyzed using the Image software, as illustrated in Fig. 4b.

#### EDS and mapping analyze

A strong X-ray diffraction evaluation of the sustainability of zero-valence photoreduction. The optical absorption range of the gold nanoparticles was observed between about 1.1 and 13.6 keV (Fig. 5), indicating the typical absorption of metallic gold. The EDX technique was used to analyze the elemental composition of the sample, as can be seen, the high purity of gold peaks, as these data evidence indicates there is a significant quantity

of Au in the sample (98.3%) with negligible levels of oxygen (1.7%), and that the presence of this percentage of oxygen is most likely due to the presence of the solvent. This confirms the purity of the structural arrangement, as there are no other interfering materials. The scanning electron microscope revealed an excellent distribution of the gold nanoparticle grains, as shown in Fig. 6. This uniformity of the gold nanoparticles gives them distinctive properties, as evidenced by the map evaluation images that reveal little scattering of oxygen, making its effect almost insignificant.

#### Transmission Electron Microscopy (TEM) analyze

TEM determined the morphology, size, and shape of the gold nanoparticles, as well as the

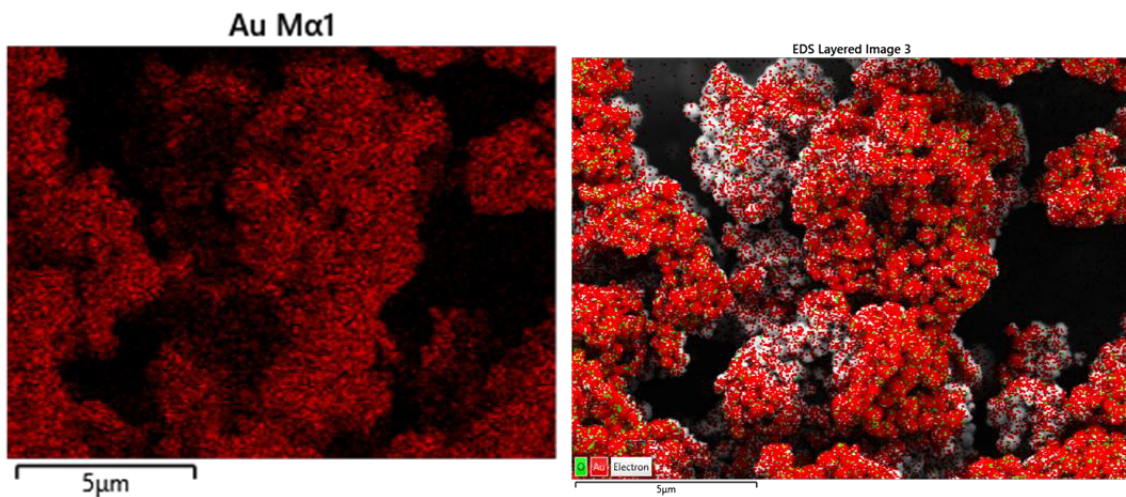


Fig. 6. EDX mapping of Zero-valence AuNPs prepared in this work.

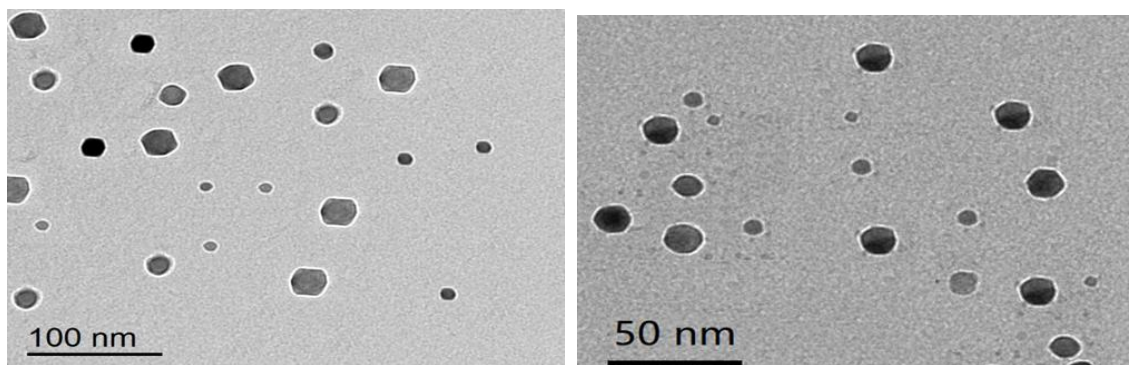


Fig. 7. Transmission electron microscopy (TEM) pics of gold nanoparticles prepared using the image-irradiation synthesis technique.

average particle size and distribution. Transmission electron microscope (TEM) images indicate that the morphology of the gold nanoparticles is cubic, with a few showing spherical characteristics of the gold nanoparticles as shown in Fig. 7. The average diameter of the gold nanoparticles prepared by the photoirradiation method was found to be 22 nm. The unique thing about the method used to make the zero-dimensional gold nanoparticles is that they don't clump together, as shown by measurements and pictures. This makes the pictures of the prepared pattern very clear. This is because the photoirradiation process using ultraviolet light led to the transformation of the gold salt into nanoparticles. Moreover, all nanoparticles fall within the nanoscale variety (drastically less than 100 nm), confirming their 0-dimensional nature. These findings align with the particle size estimations acquired from the Debye-Scherrer equation applied to the X-ray diffraction statistics.

## CONCLUSION

The new, environmentally friendly way to make 0-valent gold nanoparticles (AuNPs) through photoirradiation is a huge step toward making nanomaterials that are safe for the environment. By making use of light as an electricity source, this approach eliminates the need for hazardous chemical compounds and reduces power intake, aligning with green chemistry principles. Because the method is so flexible, it can be used with natural lowering retailers like plant extracts and biomolecules. This makes biocompatible and functionally diverse AuNPs that can be controlled in length and shape. Photoirradiation is also a good idea for big uses in areas like medicine, electronics, and catalysis because it has fast response times, can be scaled up, and leaves less of an impact on the environment. This progressive approach enhances the sustainability of nanotechnology and demonstrates the capacity for integrating renewable power resources into cloth synthesis, paving the way for more accountable and aid-efficient commercial practices. In conclusion, the photoirradiation synthesis method is a major step forward in finding more environmentally friendly ways to make nanoparticles.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this

manuscript.

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