Journal of Education for Pure Science- University of Thi-Qar
Vol.12, No2 (December, 2022)
Website: jceps.utq.edu.iq *Email: jceps@eps.utq.edu.iq*

DOI: http://doi.org/10.32792/utq.jceps.12.02.33

Fabricated and characterization of Gold nanoparticles using DC sputtering technique

Zahraa A. Jabbar, Alaa Jabbar Ghazai2

Al-Farabi University College, Iraq
Al-Nahrain University, Science College, Physics Department, Iraq

Received 15/3/2022 Accepted 22/8/2022 Published 01/12/2022

Abstract:

In this paper, Fabricated and characterization of Gold (Au) nanoparticles prepared using Direct current (DC) sputtering at optimal deposition times for antibacterial applications have been studied. X-ray diffraction patterns, scanning electron microscopy (SEM), and atomic force microscopy (AFM) images, as well as optical spectroscopy, have been used to characterize of (Au) nanoparticles. The crystalline structure of gold nanoparticle was determined using an XRD pattern which was cubic phase and polycrystalline.structure. The effect of deposition on the morphology of deposited films was visualized using a scanning electron microscope (SEM). In addition, the roughness, and surface quality, as shown by AFM results. UV-visible reflection spectroscopy was also used to investigate the optical properties of thin films.
Keywords: Au, thin film, high reflectance, DC sputtering, optical properties, structuraproperties

1. Introduction

Nano-crystalline thin solid films are currently generating a lot of interest in the scientific community, owing to their interesting new properties for technological applications (1, 2). Understanding the growth dynamics and structure of high-quality film during different stage of deposition is the most important prerequisite for its preparation. Throughout the twentieth century, numerous scientists advanced the theory of size-dependent effects in metal thin layers, and many attempts to solve these obstacle have been suggested. A significant quantum size effects focusing on difficult isolated metal behavior in 1D and 2D dimensions, which surface and quantum size effects have been observed for ultrathin metal layers. (3,4). The proportion of surface atoms increases dramatically as the size of nanoparticles reduces; as a result, such as gold nanoparticles melting point and density. (5-7). Matthiessen's rule is a mathematical formula for calculating relaxation times for multiple scattering mechanisms (8). Gold is a lustrous, and has a face-centered cubic structure, non-magnetic.

A small sample of the same gold, on the other hand, is quite different, assuming it is small enough: Green light is absorbed by 10-nm particles, which causes them to appear red. As the sample size decreases, the melting temperature drops dramatically (9). Au nanoparticles also become insulators at this size. Thin films of gold are now used in a wide variety of applications, such as Sensors (10), and many of optoelectronic devices (11).

The film quality is influenced by the structural properties of gold thin films, which can affect the device's optical properties and overall capability. at the same time Metal films of various thicknesses are required for various applications, and because these films are polycrystalline, their internal properties and surface roughness can vary greatly from one thickness to another.

In this study, fabricated and characterization which including the structural and optical properties of gold nanoparticles.

2. Experimental Part

Au thin film were deposited on glass substrate cleaned by propanol for 15 minutes by DC-sputtering method using Magnetron sputtering machine (Quorum Q150R ES) with current (10) mA and Argon (Ar) gas with vacuum chamber at room temperature, the height between Au target and the holder was 2.6 cm for all samples. The optimal thickness was 200 nm at deposition time of 1164 second depending on the deposition equation(12):

D = K I T ……….. (1)

Where D is film thickness (A),
Kis a material constant, for gold in Ar gas K~0.17
I is sputtering current (mA),
T is time (S)
Several diagnostics were employed to study deposited films. Absorption, transmission, and reflection of Au nanoparticles was recorded using UV-vis spectroscopy, Scanning Electron Microscope (SEM) images prepared by (inspect s50 from FEI) and EDX (energy dispersive X-ray spectroscopy) were prepared by (XFlash 6-10 from bruker). and X-ray diffraction (XRD) patterns were prepared, using (X'Pert PRO from PANalytical) diffractometer.

In addition, the dislocation density (δ) and strain of the films (Ɛ) were determined respectively using XRD data of the following relations:
$\delta = 1/D^2hkl$ …………….. (2)

Ɛ = □ cosΘ/4 …………… (3)

The interplanar distance (d) is calculated using Bragg's formula:
$d = n\lambda/2\sin\Theta$
and The Scherrer formula can be used to calculate the crystal's domain size from the full width at half maximum (FWHM) of the peaks
$D = K\lambda/\beta\cos\theta$ …………….(4)
k = 0.9 , λ = 1.54 , □ is (FWHM), θ is the angle between the incident beam and the reflection lattice planes. AFM analysis was done using scanning probe microscopy angstrom advanced AA2000. The AFM was in contact mode, under room temperature.

3. Results and discussion

Figure (1) shows the XRD pattern of Au nanoparticle prepared on glass substrate using DC-sputtering method. The diffraction peaks were at planes (111), (200), (220), and (300), which corresponding to 2ϴ= 37, 44, 63, and 77 respectively. The result indicated that the Au particles have good crystalline and homogeneity in the structure at the optimal thickness depend on the time of the deposition. In addition, the wide FWHM, and low strain have been observed.

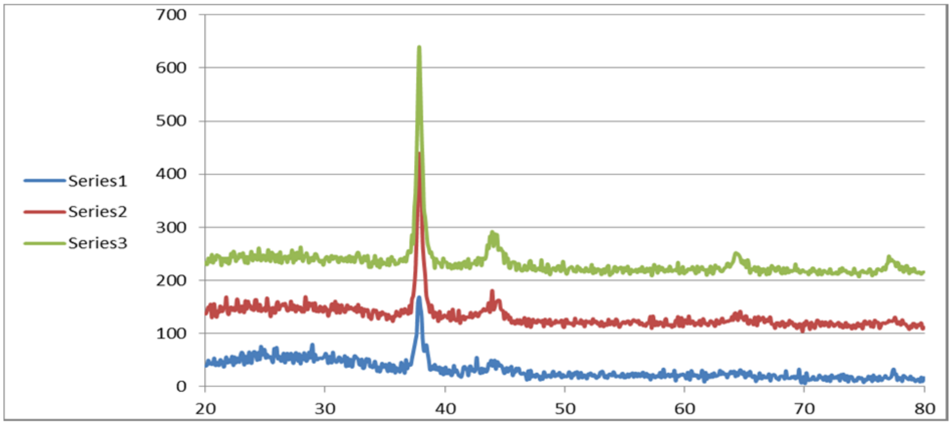

Figure (1): the XRD pattern for Au thin film deposited on glass substrate by using DC sputtering,

The XRD results have been summarized in Table (1).

Table (1): Crystalline size, FWHM, strain, and dislocation density of Au nanoparticle

2θ (degree)	hkl	d (nm)	FWHM (β)	D (nm)	Strain (ε)	Dislocation density ($1/nm^2$)
37.8666	111	2.37601	0.3936	33.30	0.0930	$9* 10^{-4}$
44.4057	200	2.04013	0.1968	65.204	0.0455	$2* 10^{-4}$
64.3267	220	1.44822	0.9840	11.923	0.2082	$70* 10^{-4}$
77.3064	311	1.23428	0.9840	10.999	0.1921	$82* 10^{-4}$

Figure (2) shows the SEM images of Au nanoparticle on glass substrate prepared by usin DC-sputtering with thicknesses of 200 nm. As can show that the morphology of Au surface is improved by optimal thickness due to the film take time which needed to arrange its atom and be more homogeneous. This is agree with XRD results.

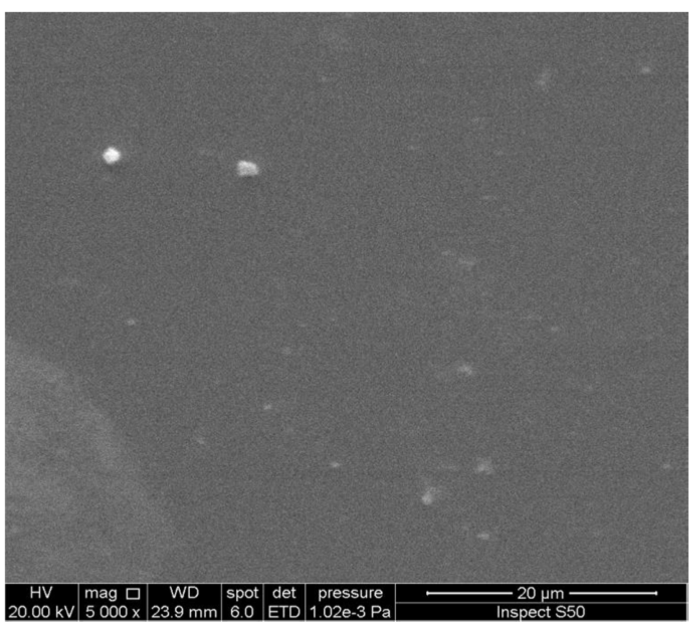

Figure (2):SEM images of Au thin film on glass substrate with thicknesses of 200 nm.

EDX analysis was performed on the slides which at thickness of 200 the result shown in Figure (3) below and the data base in Table (3)

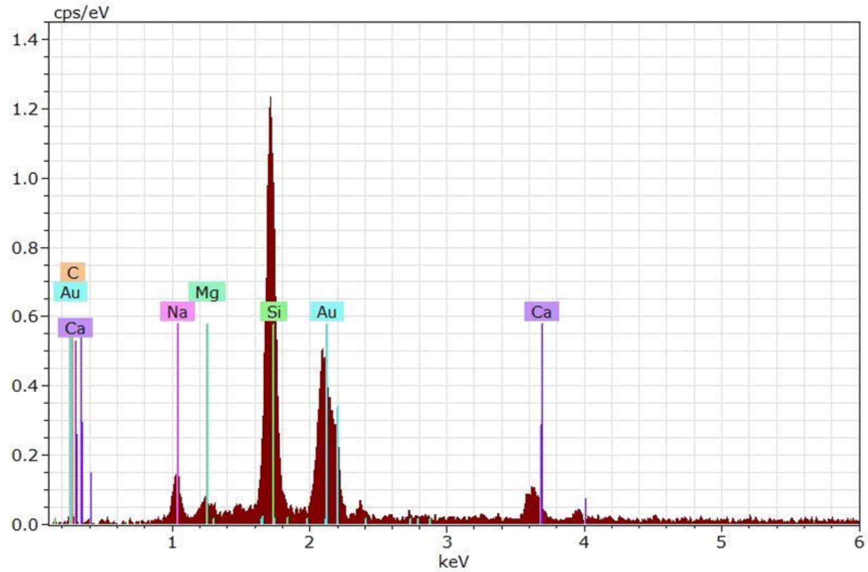

Figure (3): the EDX for Au thin film with the 200 nm thicknesses

Atomic force microscopy (AFM) was also used to perform surface analysis on thin films. The results of this test were presented as three-dimensional images in Figure (4). Figure (4) shows AFM results which including the roughness, RMS, and grain size of Au nanoparticle deposited on glass substrate by using DC-sputtering method. The roughness RMS, and grain size was increased to the high value of 6.71, of 8.83 and 7137.17 respectively with optimal thickness of 200 nm.

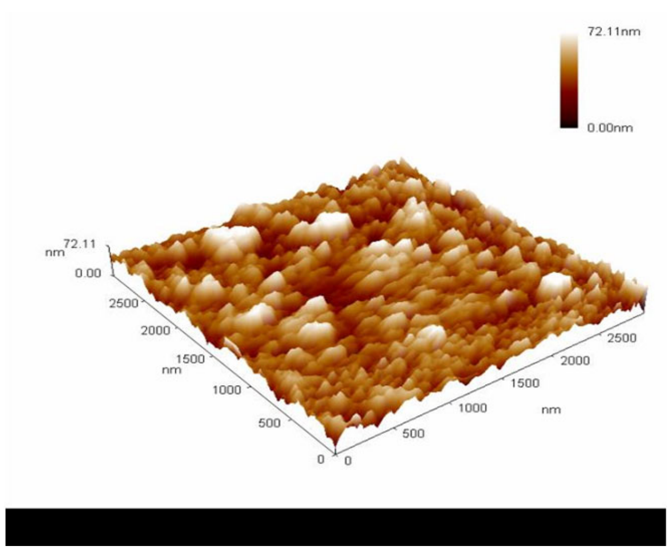

Figure (4): the topography in 3 Dimension images for Au film surface with 200 nm thickness.

Figure (5) shows the reflection as function of thickness of 200 nm. It is indicated that the flection had maximum value at ƛ~500 nm. This makes possibility to use such metal for high reflection applications.

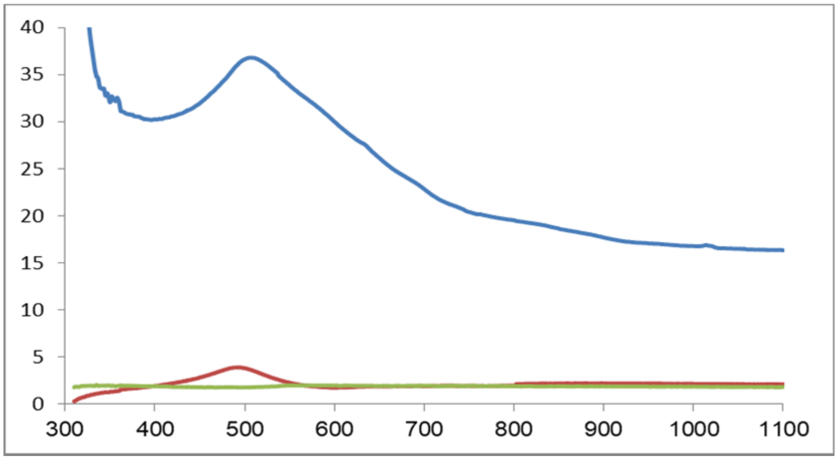

Figure (6): reflectance intensity for 100, 200, and 300 nm.

4. Conclusion

Gold (Au) nanoparticles prepared using DC sputtering at optimal deposition times for antibacterial applications have been fabricated and characterization, successfully. The cubic phase and polycrystalline in nature and homogenous crystalline structure of gold nanoparticle was observed. In addition, wide FWHM, small crystalline size and low strain were determined..

References:

1. Biswas, A. and Karulkar, P.C., 2006, June. Low cost, tailored polymer-metal nanocomposites for advanced electronic applications. In *2006 16th Biennial University/Government/Industry Microelectronics Symposium* (pp. 145-149). IEEE.
2. Hynninen, A.P., Thijssen, J.H., Vermolen, E.C., Dijkstra, M. and Van Blaaderen, A., 2007. Self-assembly route for photonic crystals with a bandgap in the visible region. *Nature materials*, *6*(3), pp.202-205.
3. Rao, C.N., 2000. R, Kulkarni G. U, Thomas P. J, Edwards PP Metal nanoparticles and their assemblies. *Chem. Soc. Rev*, *29*, pp.27-35.
4. Roduner, E., 2006. Size matters: why nanomaterials are different. *Chemical Society Reviews*, *35*(7), pp.583-592.
5. Fischer, W., Geiger, H., Rudolf, P. and Wissmann, P., 1977. Structure investigations on single-crystal gold films. *Applied physics*, *13*(3), pp.245-253.
6. Hڹupl, K., Lang, M. and Wissmann, P., 1986. X- Ray diffraction investigations on ultra- thin gold films. *Surface and Interface Analysis*, *9*(1), pp.27-30.
7. Wang, N., Rokhlin, S.I. and Farson, D.F., 2008. Nonhomogeneous surface premelting of Au nanoparticles. *Nanotechnology*, *19*(41), p.415701.
8. Chopra K: *Thin Film Phenomena*. New York: Wiley; 1969.
9. Sun, C.Q., 2007. Prog. Solid State Chem.
10. Wenzler, L.A., Moyes, G.L. and Beebe Jr, T.P., 1996. Improvements to atomic force microscopy cantilevers for increased stability. *Review of scientific instruments*, *67*(12), pp.4191-4197.
11. Lal, S., Grady, N.K., Kundu, J., Levin, C.S., Lassiter, J.B. and Halas, N.J., 2008. Tailoring plasmonic substrates for surface enhanced spectroscopies. *Chemical Society Reviews*, *37*(5), pp.898-911.
12.Amer, M. ., & Ghazai, A. J. . (2022). Effect of Films Thickness on Structural and Optical Properties of Gold (Au) Thin Films Prepared by DC Magnetron Sputtering. Iraqi Journal of Science, 63(4), 1549–1556.