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Cubic Gold Film Synthesis And Characterization For Plasmon Resonance Applications.

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ABSTRACT

As a starting point, high purity gold powder was used to create a sturdy target for electron beam evaporation. The films were placed on a 100-oriented Silica substrate that had been ultrasonically cleaned and kept at a substrate temperature of 573K. A diffusion pump was used to empty the vacuum chamber to a base vacuum of more than 10−6 Torr, allowing inert gas to enter the chamber and maintain an inert atmosphere at a vacuum of 5x10-5 Torr. With GIXRD, the films' crystallinity was examined. It was discovered that the films are polycrystalline and that their preferred (1 1 1) orientation causes them to crystallize in a cubic form. Energy Dispersive X-Ray Spectroscopy (EDS) and the Scanning Electron Microscope (SEM) were used to analyze the composition and surface morphology of these films, respectively. A stylus profilometer was used to assess the thickness of the films. Optical absorbance and reflectance studies in the 300–1000 nm wavelength range were performed on Au thin films using a UV–VIS spectrophotometer. The optical absorption data was used to compute the optical constants, such as the band gap and other characteristics. It was discovered that these films hold great potential as materials for Surface Plasmon Resonance Applications (SPR).

Keywords: cubic gold film, plasmon, high purity, SEM

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INTERDUCTION

This One of the most popular systems for studying optical, magnetic, mechanical, and electrical properties is the use of metallic thin films deposited on insulating substrates [1]. Among these, noble metallic thin films made from noble metals are of particular interest due to their unique optical properties, such as Surface Plasmon Resonance (SPR) [2], which results from an electromagnetic wave interacting with the metal's conduction electrons under light irradiation [3]. The electric field of the light wave causes electrons close to the metal's surface to oscillate collectively when the frequency of the optical excitation matches their natural frequency, a process that also maximizes energy absorption [4]. For metal nanoparticles, the SPR band's peak position is dependent on the size, shape, and composition of the particles as well as the surrounding medium's refractive index. An linked physical property of this improved absorption of light has been studied, namely the creation of heat by a metal surface under illumination. For a metal thin film system, careful nanodesign can enhance the absorption of incident photons when the light causes a resonance, the conversion of photon energy into heat energy, and the heat transmission from the thin film to the surrounding matrix. Because metal thin films have a high optical quantum yield—that is, they are poor light emitters—the heating effect is very significant for them [4]. The surface temperature of Au thin film under optical excitation has been measured as part of the analysis of this heating effect. The common techniques used to create Au thin films and nanopowders were colloidal solutions [5], lithography, thermal evaporation [6], and others. In the current work, we employed the electron beam evaporation technique to create Au thin films and examined their optical, morphological, and structural characteristics.

EXPERIMENT

Cleaning the substrate is the initial step in the deposition of Au thin films. Cleaning the substrate surface before film deposition is crucial for achieving the desired film characteristics. For this, the silicon substrates were first cleaned by immersing them in a solution of chromic acid and double-distilled water. They were then cleaned for fifteen minutes using an ultrasonicator and a detergent solution. To obtain moisture-free substrates, they were cleaned with double-distilled water, rinsed with acetone, and then dried in an oven. Utilizing the e-beam deposition technique, Au thin films were produced on silicon substrates. Diffusion and rotary pumps were used in tandem to pump the vacuum chamber.A digital pirani and penning gauge combo was used to measure the pressure inside the chamber [7].To pelletize the source material, finely ground 99.99% pure gold powder was obtained from Sigma-Aldrich chemicals. Top-mounted substrates were spaced 10 cm apart from the target material, and a little heater was used to keep the substrate's temperature at 573 K. The vacuum chamber was first kept at a base pressure of 10-6 Torr. After that, organ gas was added via a needle valve to provide an inert atmosphere, and the vacuum chamber's final pressure was kept at 5x10-5 Torr. Au thin films are deposited on silicon substrates at a substrate temperature of 573K using an e-gun. GIXRD was used to evaluate the films' structural properties, while SEM and AFM were used to examine the surface microstructural characterisation of the films. A stylus profilometer was used to assess the thickness of the films. Optical absorbance and reflectance studies in the 300–1000 nm wavelength range were performed on Au thin films using a UV–VIS spectrophotometer. The optical absorption data was used to compute the optical constants, such as the band gap and other characteristics. The e-gun was kept at a constant power level during the deposition procedure.Using a CuKα1 radiation high resolution X-ray powder diffractometer (D8-Discover system of m/s Bruker), GIXRD analysis of the materials was performed. Using nickel-filtered CuKα radiation (λ= 0.15418 nm), a voltage of 40 kV and a current of 30 mA were applied to investigate the structural and crystallographic phases present in the films. The angle of incidence of the X-rays was kept at 0.5o for all measurements, and the diffraction space was scanned over a 2θ range of 15–90o.Using the Debye Sherrer formula, the average size of the Crystallites (D) in the Au films was calculated.The length of dislocation lines per unit volume of the crystal is known as the dislocation density (δ). The crystal's dislocation density (δ) provides details about its structure. The formula below can be used to compute the dislocation density for preferential orientation [8].

The Zeiss Supra 50VP 3500 SEM was used to analyze the film morphology. Secondary electrons were employed as the detection mode and thin films were positioned on the sample holder using double-sided carbon tape. Through the use of energy-dispersive X-ray spectroscopy (EDS), the elemental composition was determined.

The Mean Roughness (Ra) and Root Mean Square (RMS) Roughness (Rq) of film are estimated using the AFM (Park systems XE-70) with a scanning area of 1μm x 1μm [7].The AMBIOS XP-1 stylus profilometer

is utilized to gauge the film thickness.Optical Absorption was performed with a Shimadzu UV-2450UV-Visible single beam spectrophotometer over the wavelength range of 300 nm to 1000 nm. Using a naked glass substrate as an optical reference, beam calibration using indium oxide thin film was used to modify the spectrum during the experiment. Both the base line and the Au thin film are represented by the recorded resultant signals. Using Lambert's principle, the absorption coefficient was computed using optical transmittance data.

$$\alpha = A(h\nu - Eg)^n$$

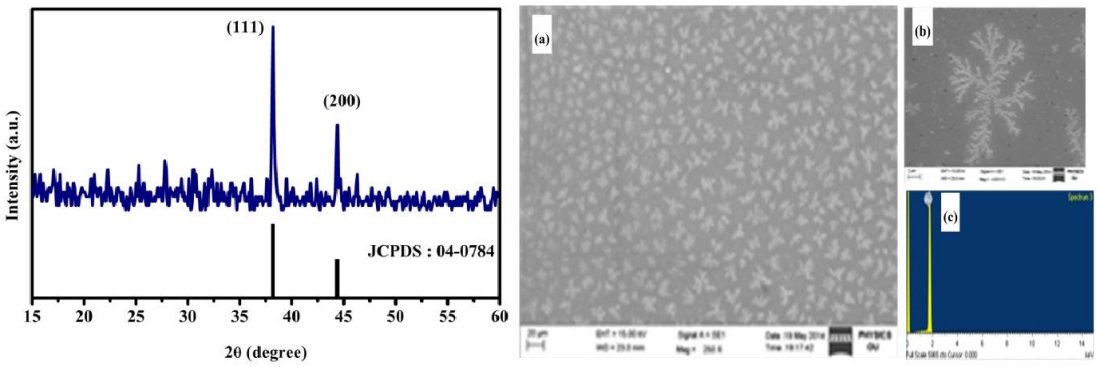
Where A is constant, υ is transition frequency and the exponent n characterizes the nature of band transition. n= ½ and 3/2 corresponds to direct allowed and direct forbidden transitions and n= 2 and 3 corresponds to indirect allowed and indirect forbidden transitions respectively [9] It is observed that the best straight line is observed for n= ½, which is expected for direct allowed transition. The value of Eg was estimated by extrapolating the straight line portion of (αhυ)2 vs. hυ.plot.

$$\alpha = \frac{A}{t}$$

where A is the Absorbance and t is the thickness of the film.

The optical band gap (E_g) of the films can be estimated using the relation

RESULTS AND DISSCUTION



[1] **[2]**

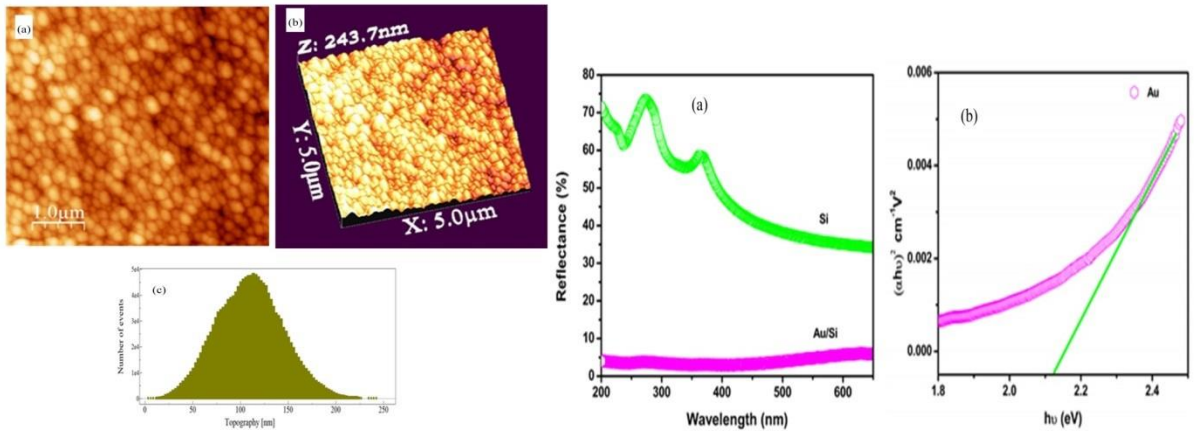
Figure 1: (1) GIXRD of Au thin film. 1.(2). (a) SEM micrograph of Au thin film, (b) Magnified view of fern like nano Au structure, (c) EDS spectra of Au thin film.

Figure 1 shows the X-Ray diffraction spectra obtained for Au thin film using the e-beam evaporation approach at a substrate temperature of 573K. Numerous reports demonstrate how GIXRD peaks related to nanostructured films can differ significantly in intensity and orientation from the bulk material. It was discovered that the Au thin film crystallizes in a cubic form and is polycrystalline in nature (JCPDS NO: 04-0784). The GIXRD pattern displayed distinct peaks with 2θ values of -38.16o and 44.4 o, which were attributed to reflections from (111) and (200).The highest level of intensity

When compared to other planes, orientation was discovered to be quite high, with (200) being the second-strongest peak. Using Debye Scherer's formula, the average crystallite size (D) from the GIXRD data was determined from the (111) diffraction peak. A mean particle size of around 26 nm was discovered. The dislocation density was approximately 0.0119. This illustrates how the Au thin films are nanometrically grained. This is due to the fact that the deposition circumstances of the films and substrate we utilize have a significant impact on the preferred orientation of crystalline growth.

SEM pictures of silicon substrates at 573K substrate temperature are displayed in Figure 1.(2)(a). It is evident from these photos that the film was created with a consistent distribution of calms. Every tranquility appears as fern (enlarged image in Fig. 1).(2) (b)) Agglomeration of Au nanosphere spherical particles may be the cause. During the deposition process, a quartz crystal monitor measuring approximately 252 nm was used to assess the film's thickness using a stylus profilometer. The elemental

analysis of the deposited film using EDS is displayed in Fig. 1.(2)(c), which validates that the Au film formed by electron beam evaporation has a satisfactory stoichiometry.



[1] **[2]**

Figure 2: 1. (a) AFM 2d micrograph of Au thin film, (b) AFM 3d micrograph of Au thin film, (c) Surface topographic of Au thin film. 2.(2). (a) Reflectance spectra of Au thin film on Si (100) substrate, (b) Tough plot to estimate energy gap of Au thin film.

The AFM 2d micrograph (5µm × 5µm) of the Au thin film on silicon substrate displays homogeneous spherical grains in Figure 2.(1) (a). It is discovered that the film's surface is continuous. The surface skewness, which measures the degree of roughness bias, was found to be 0.12 nm, indicating that the height distribution is almost symmetrical about the mean plane. The root mean square (RMS) roughness was found to be (Rq) 34.7 nm.Figure 2. (2) (a) Displays the optical reflectance spectra of the Au thin film, which were obtained between 300 and 700 nm in wavelength. It displays variations in reflectance both before and after the silicon substrate is coated with Au. Through this behavior, Au thin film is positioned favorably for Surface Plasmon Resonance Applications.

Figure 2. (2) (b) It was discovered that the Au thin film placed on the silicon substrate had improved crystallinity and structural uniformity. It was discovered that the average optical band gap was 2.1 eV. The films' lower crystallite sizes are the cause of the greater band gap value.

CONCLUSION

Nanostructured fern leaf Using an electron beam evaporation process, a thin coating of au was created on a substrate of pure silicon. According to GIXRD, the deposited film was polycrystalline with a (111) orientation; the size of the crystallites was measured to be 26 nm, and the dislocation density was found to be approximately 0.0119. SEM pictures verify that a structure resembling a nanofern has formed. Au thin film's energy band gap (2.1eV) was determined using optical absorption measurements.

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