

**DEPOSITION PLASMONIC GOLD NANOPARTICLE SENSORS PRODUCED BY PULSED LASER DEPOSITION: MORPHOLOGICAL, STRUCTURAL, AND OPTICAL CHARACTERIZATION WITH BIOCHEMICAL SENSING VIA AVIDIN BINDING**

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Abstract: Plasmonic gold nanoparticles (AuNPs) have emerged as highly sensitive platforms for biochemical sensing due to their localized surface plasmon resonance (LSPR) properties. In this study, gold nanoparticles were deposited onto glass substrates using pulsed laser deposition (PLD). The morphology of the nanoparticles was characterized using atomic force microscopy (AFM) and SEM, while their crystalline structure was investigated via X-ray diffraction (XRD). LSPR properties were examined using UV-Vis spectroscopy. Furthermore, we explored the potential of the AuNP films as biosensors by observing the shift in the LSPR peak following the binding of avidin molecules. The results show distinct morphological features, crystalline gold phase confirmation, and clear LSPR signatures. Avidin binding induced measurable shifts in the plasmonic peak, confirming the platform's sensitivity to biochemical interactions and refractive index sensing.

Keywords: Gold nanoparticles, Pulsed laser deposition, Plasmonic sensor, Localized surface plasmon resonance, Avidin, UV-Vis spectroscopy, XRD, AFM

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1. Introduction

Plasmonic nanomaterials have emerged as one of the most versatile classes of functional nanostructures, owing to their unique ability to localize and enhance electromagnetic fields through collective oscillations of conduction electrons, known as localized surface plasmon resonances (LSPRs) [1-3]. Among noble metals, gold nanoparticles (AuNPs) have attracted particular attention due to their outstanding chemical stability, biocompatibility, and tunable optical response in the visible and near-infrared regions [4, 5]. These attributes have led to the integration of AuNPs into a wide variety of applications, ranging from surface-enhanced spectroscopies and photothermal therapies to optical sensing and nanophotonic devices [6-8]. Gold nanoparticles (AuNPs) exhibit exceptional optical properties owing to localized surface plasmon resonance (LSPR), which is the collective oscillation of conduction electrons in response to incident light [9-13]. These LSPR features make AuNPs highly promising for applications in biosensing, imaging, and environmental detection [14, 15]. A small change in the local dielectric environment around AuNPs can lead to a measurable shift in the LSPR peak, enabling label-free detection of biomolecules [16, 17].

One of the most significant advantages of plasmonic AuNPs is the pronounced sensitivity of their LSPR to the surrounding dielectric environment. Even subtle molecular binding events at or near the nanoparticle surface can induce measurable shifts in resonance wavelength, enabling their use as powerful label-free biochemical sensors [6, 18, 19]. This capability has motivated extensive research on both the controlled fabrication of Au nanostructures and the exploitation of their plasmonic response for molecular detection in environmental, medical, and bioanalytical contexts.

Various synthesis and fabrication approaches have been developed for gold nanoparticles, including chemical reduction methods, colloidal growth techniques, lithographic patterning, and physical vapor deposition [4]. Chemical routes remain widespread due to their simplicity and scalability; however, they often require surfactants, reducing agents, or capping molecules, which can complicate surface functionalization and reduce sensor reproducibility. Lithographic techniques, by contrast, offer excellent control over nanoparticle size and spacing but involve complex, costly procedures and are less suited for large-area coverage.

In this context, pulsed laser deposition (PLD) has emerged as a powerful and versatile alternative [20]. PLD is a physical vapor deposition technique in which a high-energy pulsed laser ablates a solid target, generating a plasma plume that condenses on a substrate to form nanostructured films. The non-equilibrium nature of the ablation process, combined with the tunability of deposition parameters such as laser fluence, background gas pressure, and substrate temperature, allows for precise control of nanoparticle morphology, distribution, and density [21, 22]. Importantly, PLD enables the direct fabrication of Au nanoparticles on dielectric substrates such as glass, without chemical precursors or surfactants, thereby preserving clean surfaces that are particularly advantageous for sensing applications. Pulsed laser deposition (PLD) offers a controllable and clean method to deposit thin films and nanostructures of various materials, including noble metals [23-25]. PLD enables fine control over particle size, distribution, and coverage, all of which are critical in tuning the LSPR response [26]. In this study, we employed PLD to deposit plasmonic gold nanoparticles on glass substrates and investigated their morphological, structural, optical, and sensor properties.

The localized plasmonic response of PLD-grown Au nanoparticles can be readily tuned by adjusting particle size and arrangement, which makes them suitable candidates for optical biosensors. In this work, we report the fabrication and comprehensive characterization of plasmonic gold nanoparticle films produced by PLD on glass substrates. The nanoparticle morphology was investigated using atomic force microscopy (AFM) and scanning electron microscopy (SEM), while crystallinity and structural features were probed using X-ray diffraction (XRD). Optical absorption and LSPR properties were measured by UV-Vis spectroscopy, revealing clear size- and morphology-dependent plasmonic features. Finally, to demonstrate their sensing capabilities, we investigated the spectral shifts of the LSPR peak upon binding of avidin molecules - a classical biorecognition system based on the high-affinity avidin-biotin interaction [27, 28]. Our findings highlight the potential of PLD-grown Au nanoparticles as robust, clean, and tunable platforms for plasmonic biosensing.

A key test of a plasmonic sensor's sensitivity is its ability to detect specific molecular interactions. We demonstrate this by binding avidin molecules to the Au NP films and measuring the resulting LSPR shifts using UV-Vis spectroscopy. Avidin is a glycoprotein with a high affinity for biotin, making it an ideal model for assessing biosensing functionality.

2. 2. Materials and Methods

2.1. Experimental

Gold nanoparticles (AuNPs) were synthesized using a pulsed laser deposition (PLD) system equipped with a Nd:YAG laser (Continuum, Minilite II). The laser was operated in pulsed mode at its

fundamental wavelength of 1064 nm, with a pulse duration of 5 ns, a repetition rate of 10 Hz, and an output energy of 35 mJ per pulse. Although the system can generate higher harmonics (532, 355, and 266 nm), only the 1064 nm wavelength was employed, as it provides efficient absorption and stable ablation conditions for gold targets while minimizing plasma interference and surface damage. Laser pulse energy was adjusted using a neutral-density filter, with measurements taken before the focusing lens. A 50 cm focal length lens focused the beam onto the gold target at a 45° incidence angle as shown in figure 1a.

High-purity (99.99%) gold targets (Plasmaterials, USA) were mounted on a rotating holder to ensure uniform ablation. Gold's high thermal conductivity in PLD (pulsed laser deposition) mainly comes from its free-electron-dominated heat transport. In metals like gold, thermal energy is carried primarily by conduction electrons, which have a high density and long mean free path due to weak electron-phonon scattering. During PLD, this allows heat deposited by the laser to spread rapidly away from the ablation spot, reducing local overheating and stabilizing the target surface temperature. Substrates consisted of standard glass microscope slides, cleaned sequentially with alkaline detergent, isopropanol, and acetone, followed by ultrasonic cleaning and drying under nitrogen flow. A fixed target-substrate distance of 5 cm was maintained, and deposition was carried out at room temperature under high vacuum ($\sim 5 \times 10^{-7}$ mbar). In the PLD system used in this study, the gold target is mounted on a rotating metallic holder designed for efficient heat dissipation and uniform ablation. The holder allows the target to rotate during deposition to avoid local overheating and ensure homogeneous material removal. The target is not thermally isolated, allowing excess heat to dissipate through the holder structure as illustrated in the figure 1b. The substrate and target were mounted using mechanical holders designed for the PLD chamber. The glass substrates were placed on a fixed substrate holder at a target-substrate distance of 5 cm, while the gold target was mounted on a rotating holder to maintain uniform ablation. The number of laser pulses was 18,000 to obtain AuNPs with certain morphologies. XRD patterns were obtained using Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$) in the 2θ range of 20° to 80°. Diffraction peaks were identified and indexed based on the standard face-centered cubic (FCC) structure of gold (JCPDS No. 04-0784).

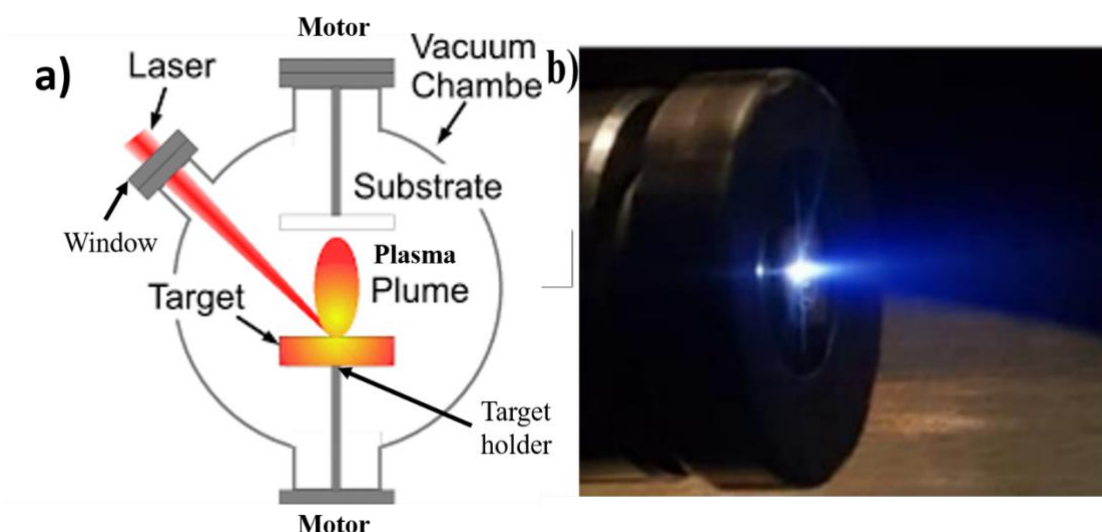


Figure 1. a) PLD system schematic, b) Au plasma appearance in the vacuum chamber.

The morphology of the deposited nanoparticles was examined using atomic force microscopy (AFM - Park System XE7-Nanoindentasyon). AFM measurements were carried out using tapping mode in ambient conditions. The surface morphology, particle height, and roughness were extracted from 5

$\mu\text{m} \times 5 \mu\text{m}$ scans. The average nanoparticle height and root mean square (RMS) roughness were calculated for each sample. Optical properties were investigated by UV–Vis spectroscopy (V-670 Jasco, USA). To evaluate plasmonic sensing performance, 20, 40, 60, 80, and 100 ppm aqueous solutions of avidin (Sigma-Aldrich) was introduced, and the localized surface plasmon resonance (LSPR) peak shifts were monitored. UV-Vis absorption spectra were recorded using a spectrophotometer in the wavelength range of 300–1100 nm. UV-Vis spectroscopy was used to record post-binding LSPR spectra, and peak shifts were compared to the pre-binding state.

3. Results and Discussion

Figure 2 shows a broad absorption band of Au nanoparticles with a plasmon resonance peak at ~ 1000 nm (indicated by the red arrow). The red arrow marks the plasmon resonance of AuNPs at ~ 1000 nm, which is much longer than the typical ~ 520 nm peak seen in small, spherical Au colloids [9, 29]. Large particle sizes are often > 50 – 80 nm. That indicated non-spherical shapes, including nanorods, elongated clusters, and irregular morphologies. Additionally, we can conclude that there may be a presence of strong particle–particle coupling due to aggregation or dense packing on glass. Figure 2 also illustrates that the peak is not sharp, but broad and flat-topped, spanning roughly 850–1050 nm. This suggests polydispersity (broad size distribution), and variation in shapes (spherical, elongated, and irregular particles) as well as possible agglomeration on the glass surface during nanoparticle deposition. The absorbance is quite high (~ 1.9 au baseline), indicating a dense nanoparticle layer is present on the glass substrate. Thus, multiple scattering and absorption events are likely, not just single plasmonic excitations.

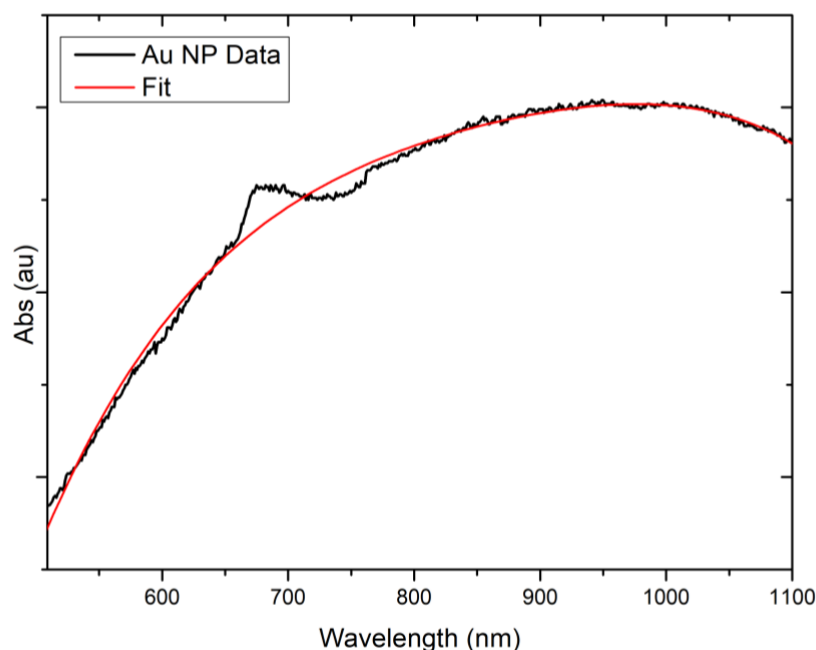


Figure 2. LSPR spectrum of plasmonic Au nanoparticles obtained by PLD.

Moreover, having an LSPR in the NIR (~ 990 nm) region is quite significant because NIR light penetrates biological tissues deeply, and that can be useful in biomedical imaging and photothermal therapy [30, 31]. The findings can be applied in plasmonic sensors that operate outside the visible range. This can also be valuable for photonic and optoelectronic devices that require NIR absorption. To summarize, the gold nanoparticles produced by PLD show a plasmon resonance at ~ 990 nm, indicating large, aggregated, and anisotropic AuNPs on glass. The broadness of the peak reflects a wide size/shape

distribution, and the high absorbance confirms a dense nanoparticle layer. The LSPR peak in the near-infrared region ($\sim 980\text{--}1000\text{ nm}$) is attributed to large or anisotropic AuNPs and strong interparticle coupling, which is consistent with the AFM observations showing polydisperse particles and aggregated structures produced by PLD deposition.

The XRD spectrum corresponds to gold (Au) plasmonic nanoparticles deposited on a glass substrate using pulsed laser deposition (PLD), as shown in Figure 3. The spectrum exhibits a broad background hump characteristic of amorphous glass (substrate contribution), centered at $20\text{--}30^\circ 2\theta$. Superimposed on this background is a broad peak in the $\sim 25\text{--}35^\circ 2\theta$ region, which could be due to nanocrystalline Au reflections broadened by small particle size. The lack of sharp, well-defined diffraction peaks suggests that the gold nanoparticles are small (nanometer scale) and possibly partially amorphous or poorly crystalline. Gold has an FCC (face-centered cubic) crystal structure (space group $Fm\bar{3}m$). The most intense reflections for bulk Au (using Cu $K\alpha$ radiation, $\lambda = 1.5406\text{ \AA}$) are at $(111) \rightarrow \sim 38.2^\circ$, $(200) \rightarrow \sim 44.4^\circ$, $(220) \rightarrow \sim 64.6^\circ$, $(311) \rightarrow \sim 77.5^\circ$ for 2θ [32].

In the XRD plot as shown in Figure 3, the expected Au peaks at 38.1° (111), 44.3° (200), 64.5° (220) appear as face centered cubic lattice, suggesting high crystallinity. Higher-order peaks are suppressed and buried in noise, suggesting a low crystalline volume fraction. The interpretation for plasmonic nanoparticles is as follows. Broad peak shapes indicate crystallite sizes in the nanometer regime. According to the Scherrer equation, peak broadening is inversely proportional to crystallite size. Here, the large width suggests crystallites in the few-nanometer to $\sim 10\text{ nm}$ range [33]. Low diffraction intensity is likely due to (a) small gold volume fraction on the glass surface, (b) preferred orientation (random particle arrangement), and (c) the strong amorphous background from glass. Plasmonic relevance is that even though the gold nanoparticles are small and weakly crystalline, their localized surface plasmon resonance (LSPR) is primarily governed by size, shape, and dielectric environment, not long-range crystallinity. The observed XRD confirms nanoscale crystallites, which are consistent with LSPR-active AuNPs. Possible reasons for low crystallinity might be due to the PLD parameters; for instance, low substrate temperature and short deposition time can lead to small, non-equilibrium clusters. Because of the glass surface mobility, gold atoms have limited surface diffusion on amorphous glass, resulting in small, isolated islands rather than large crystals. Post-deposition oxidation is unlikely for gold but contamination could further weaken diffraction intensity.

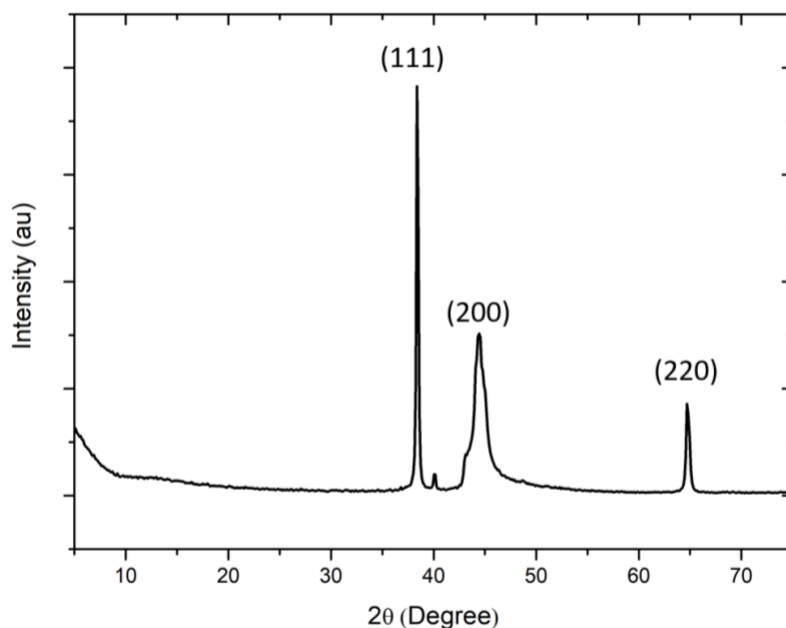


Figure 3. XRD spectrum of plasmonic Au nanoparticles obtained by PLD.

This AFM (Atomic Force Microscopy) image in Figure 4 shows the surface topography of gold nanoparticles (AuNPs) deposited on a glass substrate using pulsed laser deposition (PLD), over a $10\ \mu\text{m} \times 10\ \mu\text{m}$ scan area. The bright spots correspond to gold nanoparticles or clusters. They are dispersed non-uniformly, with some larger aggregates surrounded by smaller particles. The distribution suggests an island growth mode (Volmer–Weber mechanism), typical for PLD on glass due to poor wetting of Au on silica [34]. The color scale on the right shows height variations from $\sim 8\ \text{nm}$ (dark regions) to $\sim 200\ \text{nm}$ (brightest spots). Smaller nanoparticles are in the range of tens of nanometers, while larger aggregates exceed $100\ \text{nm}$ in height. The large particle near $(x \sim 2.5\ \mu\text{m}, y \sim 5\ \mu\text{m})$ appears to be $\sim 200\ \text{nm}$ tall, likely formed by coalescence during deposition. The background (dark red/brown) is the glass substrate with minimal Au coverage. The uneven size distribution suggests non-equilibrium growth during PLD, where plume dynamics and substrate temperature influence nanoparticle nucleation. Larger particles may form due to localized high-flux regions in the laser ablation plume or post-deposition diffusion. The presence of both small, isolated nanoparticles and large clusters suggests Ostwald ripening or coalescence occurred after initial nucleation. Glass, being an amorphous, insulating substrate, prevents uniform epitaxial growth, leading to random aggregation. A polydisperse nanoparticle layer will exhibit a broad LSPR (localized surface plasmon resonance) spectrum, as particle size and shape directly influence the plasmon wavelength. Larger particles will scatter more strongly, while smaller ones will contribute to absorption. The non-uniform spacing could also lead to plasmonic coupling effects in dense regions.

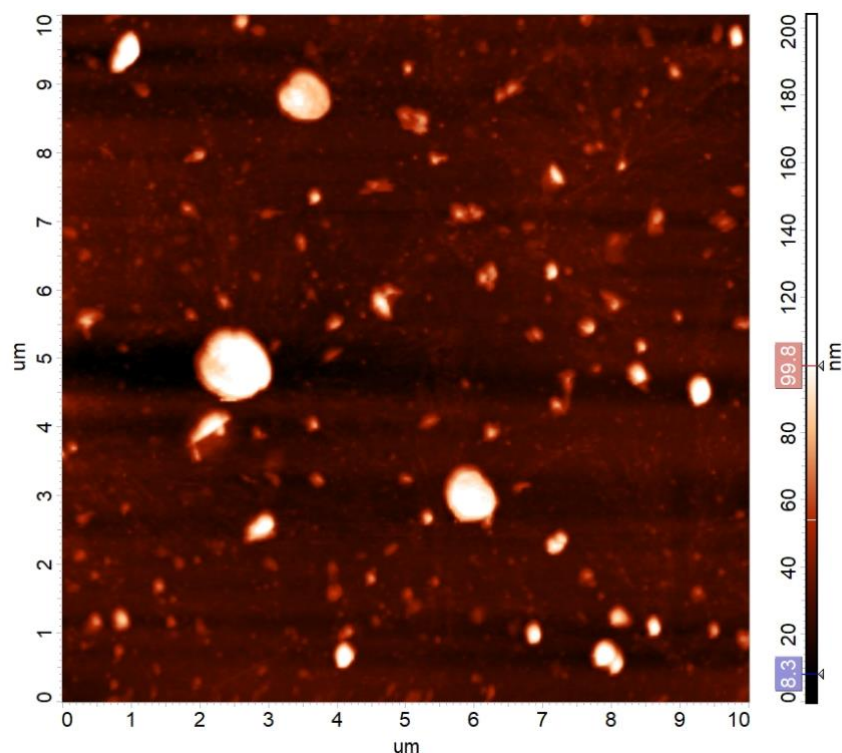


Figure 4. 2D-AFM image of plasmonic Au nanoparticles obtained by PLD.

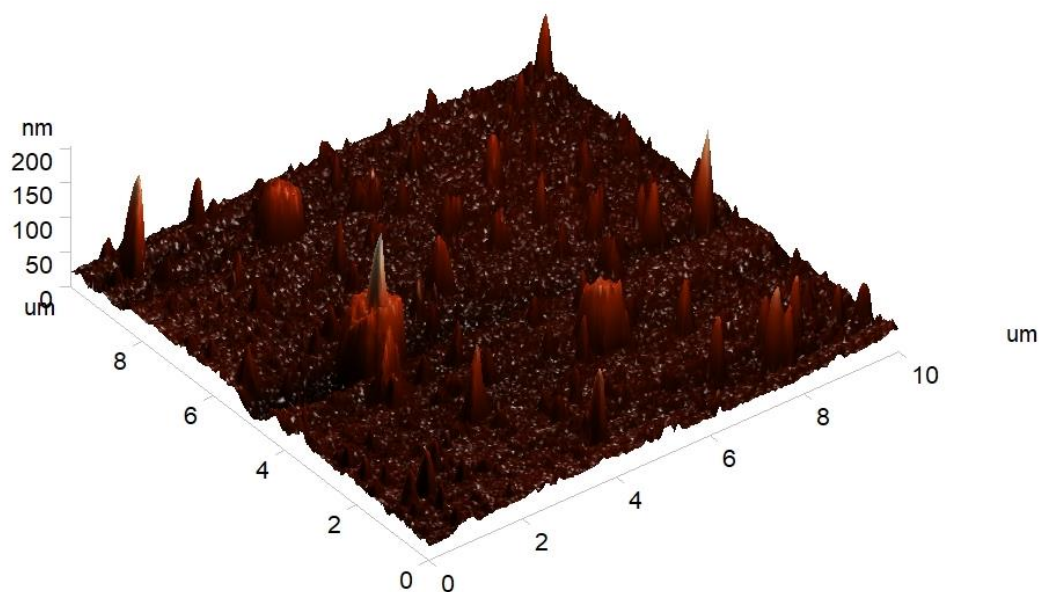


Figure 5. 3D-AFM image of plasmonic Au nanoparticles obtained by PLD.

This 3D AFM image shows the surface morphology of gold nanoparticles (AuNPs) deposited on a glass substrate using pulsed laser deposition (PLD), over a $10\ \mu\text{m} \times 10\ \mu\text{m}$ scan area, as illustrated in Figure 5. The vertical scale ranges from 0 nm to ~ 200 nm. The tall, sharp peaks correspond to larger Au nanoparticles or aggregates, while the lower features represent smaller nanoparticles. The particle heights vary significantly, indicating a polydisperse size distribution. Nanoparticles are distributed unevenly across the surface. Some regions have isolated large particles, while others show clusters of smaller nanoparticles. This is typical for Volmer–Weber island growth mode, which occurs when the deposited material has poor wetting on the substrate (e.g. gold on glass) [35]. The background substrate shows a relatively smooth base surface. RMS roughness is likely dominated by the tall nanoparticle clusters, which contribute strongly to optical scattering and plasmonic coupling. PLD generates a plume of ablated gold species that condense on the substrate. The particle size variation may be due to: Local variations in the deposition flux. Coalescence of smaller particles during or after deposition. Surface diffusion is minimal on amorphous glass but possible at higher substrate temperatures. Large particles (~ 200 nm) will scatter strongly and may contribute to red-shifted localized surface plasmon resonance (LSPR) peaks. Smaller particles (< 50 nm) mainly contribute to absorption. The mixed sizes may produce a broad LSPR spectrum rather than a single sharp peak. Clusters and close-packed regions can lead to plasmonic coupling, which affects sensing sensitivity.

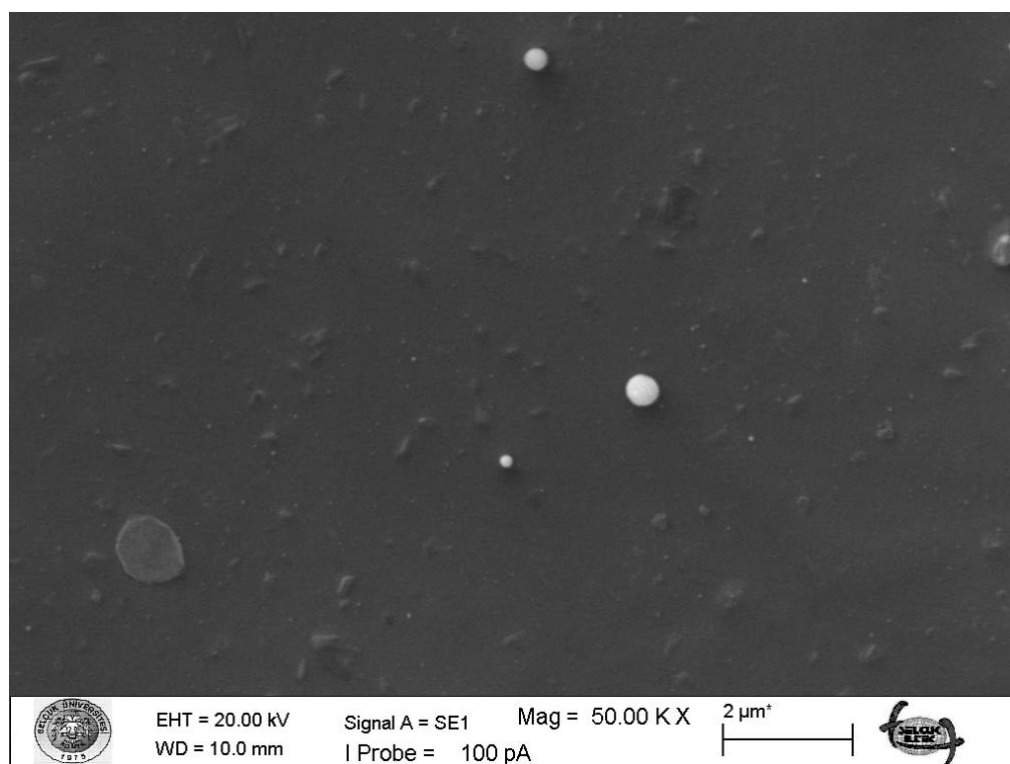


Figure 6. SEM image of plasmonic Au nanoparticles obtained by PLD.

Figure 6 presents Au nanoparticles' SEM image deposited on soda-lime glass substrates by PLD. The graph shows discrete, well-separated nanoparticle formation distributed across the substrate surface. The produced nanoparticles demonstrate predominantly spherical morphologies, indicating that the growth process was governed by nucleation and subsequent particle coalescence during PLD. No continuous Au film formation was observed, implying that the deposition parameters favored island growth instead. The particle population includes both large and small nanoparticles, suggesting a relatively broad size distribution. The largest nanoparticles have diameters of approximately 80–120 nm, whereas numerous smaller nanoparticles are also visible throughout the substrate. The low particle density and large interparticle spacing minimize plasmonic coupling effects and support the generation of localized electromagnetic fields around individual nanoparticles. Furthermore, the absence of significant agglomeration demonstrates the PLD's effectiveness in producing uniformly dispersed Au nanostructures. Based on the SEM image, it may be deduced that the average particle diameter to be closer to 90–100 nm, which is in very good agreement with the AFM measurements (~80 nm).

Figure 7 demonstrates the Au NP in pure water spectrum, in which nanoparticles were produced on glass by PLD. The curve in the Figure shows a LSPR peak at ~980 nm which corresponds to near-IR region. Peak height for intensity is around ~0.33–0.34 au at the maximum. On the other hand, the baseline slowly rises from ~0.06 au (500 nm) to ~0.16–0.17 au (~900 nm), then the plasmon band shoots up swiftly. Meanwhile a shoulder features appear with a gentle plateau around 800–900 nm before the main peak, typical of shape/size dispersion or coupled modes. Interpretation for the red-shifted (NIR) can be stated for a few reasons. The elongated/irregular particles (i.e. chains, fused clusters) support a longitudinal plasmon in the NIR. As a result of coupling, close interparticle spacing on glass (from PLD) enhances near-field coupling, inducing additional redshift. Due to the effect of environment, water ($n \approx 1.33$) and glass substrate (effective higher index than air) both push the resonance to longer wavelengths. In terms of linewidth (FWHM), crossing points are ~945–955 nm (rising) and ~1005–1015 nm (falling). The estimated FWHM is around ≈ 60 –80 nm (after baseline subtraction). This

suggests a broader than a monodisperse colloid stemming from polydispersity and coupling. When particle size/morphology is qualitatively taken into account, presence of a strong NIR longitudinal mode suggests effective sizes >50 nm and aspect ratios $\sim 3\text{--}5$ (typical range to place Au nanorod LSPR near $1\text{ }\mu\text{m}$ in water). Additionally, the shoulder and width indicate a mix of shapes/sizes and some aggregates as well. Table 1 summarises findings for Au NP in pure water spectrum.

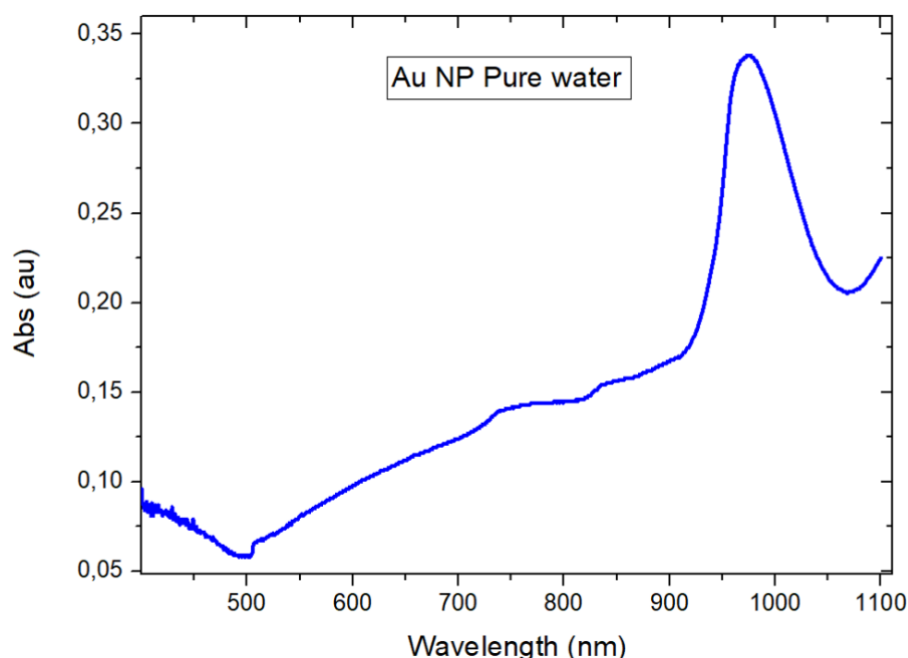


Figure 7. UV-Vis spectrum of plasmonic Au nanoparticles with pure water.

Table 1. Summary of findings for Au NP in pure water spectrum

Property	Value (approx.)	What it means
LSPR peak	~ 980 nm	Longitudinal plasmon in NIR (anisotropy + coupling + higher n environment)
Peak absorbance	$\sim 0.33\text{--}0.34$ au	Moderate loading/concentration
FWHM (baseline-corrected)	$\sim 60\text{--}80$ nm	Polydisperse distribution; interparticle coupling
Morphology (inferred)	elongated/aggregated AuNPs; effective sizes >50 nm, AR $\sim 3\text{--}5$	Consistent with PLD films and NIR LSPR

Figure 8 demonstrates a UV-Vis spectrum of plasmonic gold nanoparticles (AuNPs) interacting with Avidin biomolecules at different concentrations ranging from 20 to 100 ppm. The graph features samples of AuNPs with Avidin at 20, 40, 60, 80, 100 ppm. Broad plasmon resonance peak appears around 975 nm in the NIR region. Peak intensity slightly increases with higher Avidin concentration while the peak position remains almost the same. The peak at around ~ 975 nm corresponds to the longitudinal plasmon mode of anisotropic/aggregated AuNPs. The peaks being in the near-infrared (NIR) indicate large or elongated particles (i.e. clusters). This is due to strong particle–particle coupling from dense PLD films. Moreover, that indicates the influence of the dielectric environment composed of Avidin molecules, water, and glass substrate.

The effect of Avidin Concentration rising from 20 to 100 ppm is determined as follows. The absorbance intensity gradually increases with concentration. This is due to biomolecular adsorption, which means Avidin molecules coat the Au NP surface, slightly increasing the effective refractive index around the particles. This enhances light–matter coupling and amplifies the plasmon band. The LSPR does not shift strongly in wavelength, which means the binding of Avidin does not drastically change NP shape/aggregation, but mostly changes the dielectric environment.

In terms of linewidth at FWHM, crossing points are around ≈ 945 – 950 nm at the rising edge and 1000 – 1010 nm at falling edge. The estimated FWHM is about ≈ 60 nm. This relatively broad linewidth indicates polydispersity and some aggregation, however is narrower than the bare Au NP film on glass (without water), suggesting Avidin helps stabilize the NP surface. The peak is about $\lambda_p \sim 975$ nm in the NIR plasmon, which is useful for biosensing and biomedical optics (bio-transparency window). Intensity increase with Avidin concentration suggests direct evidence of biomolecular interaction and possible application in plasmonic biosensing (quantification of protein concentration). On the other hand, stable λ_p position indicates an adsorption-dominated effect, not restructuring of nanoparticles.

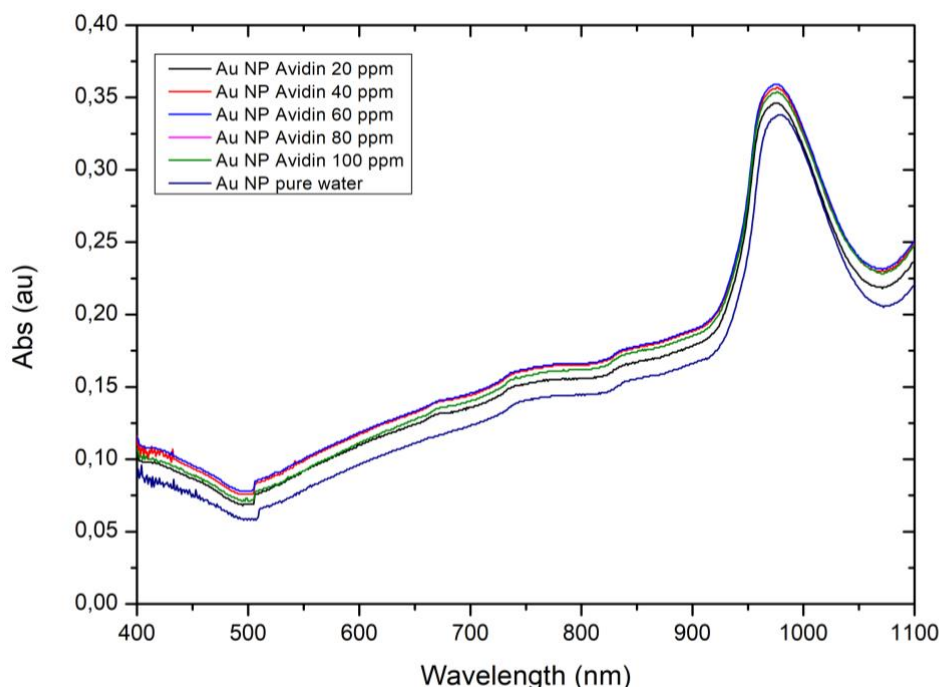


Figure 8. UV-Vis spectrum showing plasmonic gold nanoparticles interact with Avidin biomolecules at different concentrations.

To conclude, Au NP–Avidin samples show a plasmon resonance around 975 nm. With increasing Avidin concentration (20–100 ppm), the plasmon peak intensity increases, confirming molecular adsorption and refractive index changes around the nanoparticles. The peak position remains stable, meaning the nanoparticles themselves are not drastically altered in size/shape. The FWHM ~ 60 nm suggests a moderately polydisperse system, but Avidin binding may improve NP stability compared to bare colloids. Table 2 below illustrates a comparison of two Au NP spectra, both produced by PLD on glass.

Table 2. Au NP in Pure Water vs Au NP with Avidin (20–100 ppm)

Feature	Pure water	+ Avidin (20→100 ppm)	Indication
LSPR peak (λ_p)	~980 nm	~975 nm (nearly constant across 20–100 ppm)	Avidin adsorption does not restructure particles; any tiny blue shift is likely from reduced interparticle coupling offsetting the index increase.
Peak intensity	~0.33–0.34 au	Grows slightly with concentration (highest curve ~0.35–0.36 au)	Protein coating raises local optical density and dampens scattering losses → stronger band. Useful for sensing via ΔA .
FWHM (baseline-corrected)	~60–80 nm	~55–65 nm	Slight narrowing suggests surface stabilization (less coupling/aggregation dispersion) when Avidin coats the NPs.
Pre-peak shoulder(800–900 nm)	Present	Still present but slightly cleaner	Consistent with a mix of shapes, Avidin reduces hetero-coupling slightly.
Baseline	Rises from ~0.06 to ~0.16–0.17 au	Similar baseline; overall offset slightly higher at larger ppm	More adsorbate and/or loading increases overall absorbance slightly.

From the table 2, one can interpret that Avidin raises the local refractive index (would redshift λ_p), but it also sterically separates particles and passivates their surfaces (reduces near-field coupling, which blueshifts). The net outcome is a small spectral shift, however, a clear intensity increase, and mild peak narrowing. Morphology inference suggests that NIR plasmon resonance (~975–980 nm) still indicates elongated/aggregated or coupled AuNPs typical of PLD films; Avidin mainly tunes the environment rather than geometry.

Figure 9 shows the actual peak LSPR values (from 978.45 to 970.52 nm) as the Avidin–Au NP concentration is altered. The graph shows the UV–Vis–NIR absorption spectra of plasmonic gold nanoparticles (AuNPs) deposited on a glass substrate by PLD, measured in the presence of Avidin molecules at different concentrations (20–100 ppm). The nanoparticles exhibit a localized surface plasmon resonance (LSPR) peak in the near-infrared (NIR) region, whose position and intensity vary systematically with Avidin concentration. Peak Wavelength (λ_p) of the LSPR blue shifts (~8 nm total) with increasing Avidin concentration as given in Figure 10. Absorbance increases slightly as concentration rises, showing stronger resonance at higher Avidin levels. A small reduction in linewidth is observed with higher Avidin concentrations, indicating improved NP stability and reduced inhomogeneous broadening. Blue Shift of LSPR (978 → 970 nm) can be due to several reasons. Normally, adding biomolecules increases the local refractive index, which would cause a red shift. However, here we see the opposite (blue shift). This suggests that Avidin adsorption passivates NP surfaces and reduces interparticle plasmonic coupling by steric separation. Net effect suggests that decreased near-field interactions dominate over dielectric effects, and thus resulting in a blue shift. Furthermore, higher absorbance indicates more efficient plasmon excitation, caused by enhanced local refractive index contrast. Avidin effectively stabilizes NP surfaces, suppressing energy losses due to aggregation. Narrower FWHM suggests less heterogeneity and greater particle stability. Lastly, Avidin acts as a capping layer, preventing uncontrolled aggregation and damping effects. Avidin molecules adsorb onto the AuNP surface through protein–surface interactions and electrostatic forces, forming a molecular layer around the nanoparticles. This adsorption changes the local dielectric environment and interparticle spacing, which affects plasmonic coupling. In conclusion, PLD-produced AuNPs on glass show a strong NIR plasmon mode (~975 nm). Avidin binding induces a concentration-dependent blue shift (~8 nm), increases absorbance, and slightly sharpens the peak. This behavior confirms that plasmon

resonance is sensitive to biomolecule adsorption, and AuNPs can be used as plasmonic biosensors for Avidin detection.

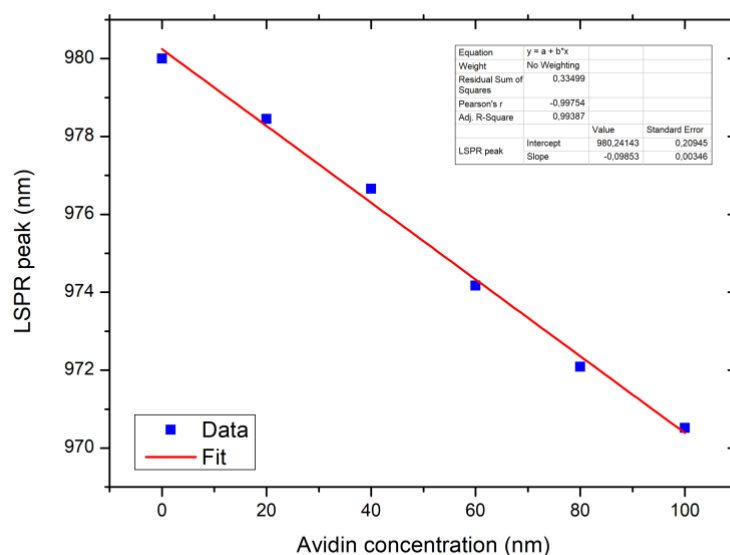


Figure 9. LSPR peak versus Avidin concentration.

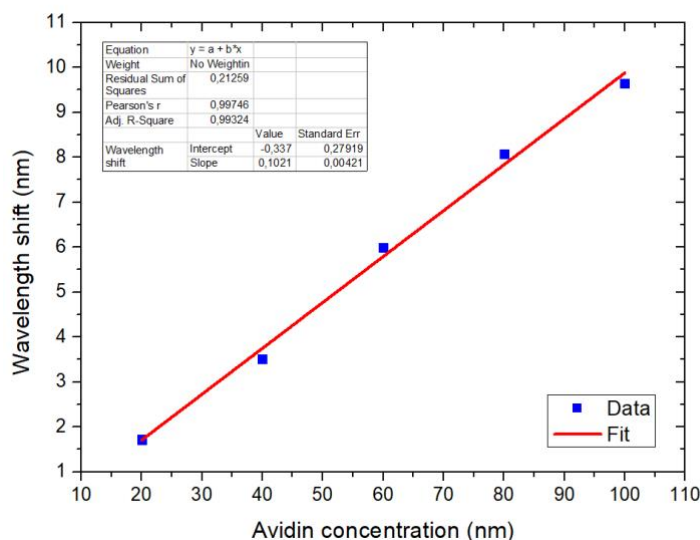


Figure 10. Wavelength shift as the Avidin concentration varies.

4. Conclusion

In this study, we have demonstrated the successful fabrication of plasmonic gold nanoparticle (Au NP) films on glass substrates using pulsed laser deposition (PLD) and evaluated their potential as optical biosensors. Comprehensive characterization of the nanostructures was carried out using atomic force microscopy (AFM) and SEM which revealed nanoscale particles with a heterogeneous distribution in size and morphology. X-ray diffraction (XRD) confirmed the face-centered cubic crystalline structure of the nanoparticles, with broadened reflections indicative of small crystallite sizes. Optical absorption spectra recorded by UV–Vis spectroscopy exhibited distinct localized surface plasmon resonance

(LSPR) peaks, whose positions and bandwidths correlated with nanoparticle size and surface distribution.

To assess sensing functionality, we investigated the spectral response of the PLD-grown AuNPs upon binding of avidin molecules, a well-established biorecognition system. The LSPR peak exhibited measurable blue-shifts upon avidin attachment, consistent with changes in the local dielectric environment surrounding the nanoparticles. This result confirms the ability of PLD-fabricated Au NP films to function as sensitive transducers for biochemical detection without requiring additional surface modification or complex nanofabrication steps.

The significance of this work lies in the demonstration that PLD, a clean and versatile physical deposition technique, can directly produce plasmonic Au nanoparticles on dielectric substrates with sufficient morphological and structural control to enable robust optical sensing. Unlike chemical methods, PLD avoids the use of surfactants and capping agents, resulting in clean surfaces that are favorable for biomolecular interactions. Moreover, the tunability of deposition parameters provides a pathway to engineer nanoparticle size, density, and optical response for targeted sensing applications.

Overall, these findings establish PLD-grown Au nanoparticles as a promising platform for label-free plasmonic biosensing. Future work may focus on extending this approach to other biomolecular systems, integrating the sensors into microfluidic platforms, and optimizing deposition conditions to tailor LSPR sensitivity for specific diagnostic or environmental monitoring applications.

Ethical Statements

The author declares that this document does not require ethics committee approval or special permission. Our study does not cause any harm to the environment.

Conflict of interest

The authors declare no conflict of interest.

Authors' Contributions

IC (35%) and SYG (30%) carried out the experiments and wrote the original draft. HBG (15%) and HSK (20%) supervised the work and contributed to conceptualization and methodology. All authors discussed the results and formal analysis and contributed to the manuscript. All authors read and approved the final manuscript.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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