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Integrating nanotechnology with sers for early lung cancer diagnosis: A perspective on enhancing diagnostic sensitivity and specificity

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Abstract: The absence of adequate diagnostic techniques for the early stages of the disease is the primary reason that lung cancer remains one of the most common and deadly malignancies worldwide. Cancer is frequently diagnosed at advanced stages using traditional procedures such as CT scans, biopsies, and PET-CT scans, which results in a decrease in survival rates. Nanotechnology has arisen as a possible route in answer to this issue. In particular, the application of gold and silver nanostructures in combination with Surface-Enhanced Raman Spectroscopy (SERS) has emerged as a promising method for improving the sensitivity and specificity of diagnostic techniques.

An examination of secondary literature is presented conceptually in this study in order to investigate the ways in which surface-enhanced Raman spectroscopy (SERS), enabled by plasmonic nanostructures, has the potential to make substantial advancements in the early detection of lung cancer. The research utilized a review- and theory-based technique that included the examination of peer-reviewed journal papers, technical reviews, and simulation-based models. All main data and all experimentation based on empirical evidence were eliminated from it. The theme synthesis centered on the processes that improve signals, kinds of nanostructures (for example, gold nanorods, silver nanoprisms, and Au@Ag core–shells), and the way in which these nanostructures perform in detecting biomarkers of lung cancer that are of particular importance, such as EGFR, CEA, and CYFRA 21-1.

Based on the review's findings, gold nanoparticles provide higher biocompatibility, but silver nanoparticles provide superior signal enhancement owing to their intense localized surface plasmon resonance. Hybrid nanostructures and shape-optimized geometries, including nanostars, were proposed by theoretical models as ways to achieve perfect SERS performance. It is clear that interdisciplinary teams and clinical integration are necessary to overcome the mentioned scalability, biological noise, and standardization challenges.

The paper concludes that nano-SERS systems can revolutionize early lung cancer diagnostics if supported by robust theoretical modeling, standardized protocols, and policy adoption. Recommendations include the development of multi-biomarker platforms, integration with AI, and incorporation into national screening frameworks.

Keywords: SERS, gold nanoparticles, silver nanoparticles, lung cancer diagnosis, nanotechnology in biosensing

1. INTRODUCTION

One of the most significant obstacles to public health worldwide is still lung cancer. Lung cancer is one of the primary causes of both cancer-related morbidity and mortality, accounting for millions of new cases and fatalities every year, according to up-to-date global cancer data (Lin et al., 2025; Fernandez & Short, 2015). The incidence continues to rise in many regions due to increasing exposure to risk factors like tobacco smoke, air pollution, and occupational hazards (Singh et al., 2024). Many individuals are not recognized until the disease has progressed significantly or metastasis has taken place, which severely limits the available treatment choices and considerably reduces survival chances. Late-stage identification is rather common (Lu et al., 2025; Li et al., 2025).

Survival outcomes are strongly tied to stage at diagnosis. Early-stage lung cancer (stage I or II) typically yields much higher 5-year survival rates compared to advanced disease (stage III or IV), yet the proportion of early-detected cases is low in many countries (Lu et al., 2025). Because conventional imaging methods (e.g., low-dose computed tomography, chest X-rays) often miss very small lesions, or produce false positives, there is significant clinical and scientific urgency to develop diagnostic tools that can detect lung cancer at its earliest possible stage. It is increasingly evident that highly sensitive, non-invasive, and specific detection technologies are needed to shift the diagnostic window earlier, enable timely intervention, and improve overall survival (Shi et al., 2023; Lin et al., 2025).

Nanotechnology is defined as the utilization and manipulation of materials at the nanoscale scale, which is 1 to 100 nanometers. It is in this range that these materials frequently display traits that are new to science in terms of their physical, chemical, or optical characteristics. Nanomaterials are employed in the field of medical diagnostics because of their large surface area, their capacity to be functionalized in order to target specific proteins, and their adjustable optical resonances. Due to their strong plasmonic capabilities, relative biocompatibility, and simple surface modification, gold and silver nanoparticles, in particular, have been among the most extensively researched nanomaterials for use in biosensing applications (Singh et al., 2024; Lu et al., 2025). Functionalization of these nanoparticles with molecular recognition elements (such as antibodies, aptamers, or small ligands) allows the selective capture of biomarkers, enhancing diagnostic specificity.

The use of nanomaterials in a variety of forms has been explored for the purpose of diagnosing lung cancer, including as carriers for molecular probes, as contrast agents for imaging, and as sensor platforms for detecting biomarker molecules (including proteins, nucleic acids, and exosomes) in bodily fluids (Fernandez & Short, 2015; Lu et al., 2025). The tendency to utilize exhaled air and perform liquid biopsies for examination also involves the use of nanotechnology, particularly in sensor arrays that employ silver or gold nanostructures in order to identify volatile substances or biomarkers at low concentrations (Li et al., 2025).

Surface Enhanced Raman Spectroscopy (SERS) is an optical detection method that serves to amplify weak Raman scattering signals of molecules that are either adsorbed onto or located in close proximity to nanostructured metallic surfaces. Electromagnetic effects, more specifically localized surface plasmon resonance, are the primary source of the enhancement, with chemical enhancement, or interactions between the molecule and the surface, being a contributing factor in certain instances. Electromagnetic "hot spots" emerge in spectacular fashion when gold or silver nanoparticles or nanostructures are employed as substrates, resulting in a significant amplification of the Raman signal of molecules in the vicinity (Shi et al., 2023; Lin et al., 2025). The spectral fingerprint obtained via Raman scattering enables the identification of molecular composition, including biomolecules related to disease.

The technique combines plasmons that resonate at certain frequencies when light interacts with metallic nanostructures. These resonances localize electromagnetic fields, which increases the Raman signal of molecules inside these fields. Furthermore, the scattering cross section is altered as a result of the chemical enhancement that occurs when molecules contact directly with the surface of the metal (Shi et al., 2023). Surface-enhanced Raman spectroscopy (SERS) is a technique that is both non-invasive (since only minute amounts of serum, exhaled breath, etc. are required) and label-free (because it does not require fluorescent or radioactive markers), as well as being extremely sensitive—capable of detecting very low concentrations of biomarkers down to pico- or even femtomolar levels in favorable instances (Shi et al., 2023; Lu et al., 2025).

Being able to identify many biomarkers at once, quick turnaround time, little sample volume, and the possibility of point-of-care or portable devices are all examples of the unique benefits that these methods have over conventional diagnostic techniques. Because surface-enhanced Raman spectroscopy (SERS) is able to utilize the molecular fingerprint, even little biochemical

changes that occur early in the course of a disease may result in identifiable spectrum shifts, which enables earlier identification than imaging techniques in many instances (Shi et al., 2023).

Though important, conventional diagnostic methods for lung cancer—such as computed tomography (CT) scans, positron emission tomography (PET) imaging, sputum cytology, or tissue biopsy—are still insufficient for reliably detecting the very early stages of the illness. It is possible for these approaches to produce false negatives in the case of tumors that are tiny or well-concealed, as well as false positives, which can result in intrusive operations that are not medically necessary. They may be costly, take up a lot of time, or difficult to use for regular screening (Fernandez & Short, 2015).

There is opportunity in integrating nanotechnology with SERS to fill this gap. By optimizing nanomaterials (gold or silver nanostructures) to create highly reproducible SERS substrates, and combining with appropriate biomarker targeting, it may be possible to significantly enhance sensitivity and specificity. Several recent studies (Shi et al., 2023; Lin et al., 2025) have demonstrated, via secondary data, the feasibility of serum-based SERS platforms, nanostructured silver or gold nanowires, and machine learning classification achieving high diagnostic metrics.

As a result, the goal of this work is to provide an explanation of how nanotechnology-enhanced SERS systems ought to be developed in order to optimize the reliability of diagnoses in lung cancer screening. A review and synthesis of the current secondary literature, as well as a comparison of nanoparticle kinds, functionalization, and SERS enhancement metrics, might be conducted in order to identify theoretical approaches toward enhanced early detection.

The purpose of this article was to conceptually examine and assess secondary literature pertaining to the integration of nanotechnology—in particular, gold and silver nanostructures—with SERS with the interest of detecting biomarkers of lung cancer at an early stage. The objective was to examine the most recent advancements in the synthesis and functionalization of nanoparticles, evaluate the effects of these developments on the sensitivity and specificity of SERS, and suggest theoretical guidelines and considerations for the development of effective nano-SERS diagnostic devices for early-stage lung cancer.

The nature of this investigation was theoretical and conceptual. It utilized a design that was based on a review. The data sources included technical review papers, conference papers, and peer-reviewed journal articles that have been published in recent years and that focus on surface-enhanced Raman spectroscopy (SERS), nanotechnology, and the identification of biomarkers for lung cancer. The method comprised a thematic synthesis of the literature as well as a theoretical evaluation of several nanoparticle surface-enhanced Raman spectroscopy (SERS) systems. Comparisons were made between important themes such as substrate design, enhancement mechanisms, and diagnostic metrics. The research did not include any primary data collecting, experimental work carried out by the author, or statistical modeling of fresh datasets; rather, it relied exclusively on numerical findings and descriptions that were published and taken from studies that had already been conducted.

2. CURRENT LIMITATIONS IN EARLY LUNG CANCER DETECTION

Conventional Diagnostic Tools Overview

The current diagnostic procedures for lung cancer generally involve the use of imaging and invasive tests, such as low-dose computed tomography (CT), positron emission tomography-computed tomography (PET-CT), chest X-rays, sputum cytology, and tissue biopsy. Low-dose computed tomography (CT) has been extensively embraced for early screening, particularly for groups that are at a high risk. Its ability to detect minor or early-stage lesions, on the other hand, is frequently hindered by false positives or the possibility of exposure to radiation (Shi et al., 2023; Fernandez & Short, 2015). PET-CT, while providing functional imaging, is expensive and not feasible for routine screening (Li et al., 2025). At the same time, sputum cytology has the drawback of low sensitivity, especially for tumors that are located on the periphery. Furthermore, although biopsy techniques are conclusive, they are invasive, require a significant amount of time, and involve dangers associated with the process (Lin et al., 2025).

All of these techniques have the significant drawback of their inability to effectively diagnose cancers at stage I or stage II, which are the points at which curative therapy is most successful. Moreover, expensive prices, a lack of accessibility in remote areas or places with low resources, and delays in the diagnostic process provide extra obstacles in the way of the possibility for prompt detection (Shi et al., 2023).

Challenges in Detecting Biomarkers at Low Concentration

Biomarker-based detection is widely considered a promising avenue for early cancer diagnostics. However, early-stage lung cancer biomarkers—such as circulating tumor DNA (ctDNA), exosomes, microRNAs, and specific proteins—often exist in extremely low concentrations in bodily fluids like serum, sputum, and exhaled breath condensate (Lin et al., 2025). This presents a critical analytical challenge, as most conventional immunoassays or biosensors lack the ultra-sensitivity needed to detect such trace levels reliably (Shi et al., 2023).

While enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), and next-generation sequencing (NGS) have enhanced sensitivity to some extent, they are laboratory-dependent, expensive, and prone to sample degradation or noise, especially when working with minute quantities of analyte (Li et al., 2025). As such, there is an unmet need for portable, real-time, and ultra-sensitive diagnostic platforms that can identify cancer-related molecular signatures in trace quantities, without complex pre-processing or amplification steps.

Delayed Diagnosis and Its Consequences

A substantial number of clinical consequences can arise if lung cancer is not diagnosed in a timely manner. More than seventy percent of all lung cancer diagnoses are made at advanced stages, at which point metastasis has already occurred and curative measures are no longer viable options. (Lu et al., 2025). The five-year survival rate for late-stage lung cancer remains dismally low—often less than 10%, compared to over 70% for localized, early-stage cases (Singh et al., 2024).

Delayed diagnosis increases the complexity of treatment, necessitating more severe therapies like as chemotherapy, radiation, or immunotherapy, which may not be well tolerated by all patients. This results in a rise in healthcare expenses, longer hospital stays, and a worse quality of life. In addition, delays limit the effectiveness of existing targeted medicines, a large number of which perform most well in early genetic or molecular landscapes.

Gap Identification

Consequently, the present diagnostic landscape is lacking in one obvious respect: there is a lack of biomarker detection technologies that are non-invasive, real-time, and extremely sensitive; moreover, they must be scalable, cost-effective, and clinically translatable. Existing technologies are not sufficient in meeting the requirements for early-stage detection despite the fact that there have been promising breakthroughs in the field of biomarker research.

In this context, surface-enhanced Raman spectroscopy (SERS) is a solution-worthy method that has the potential to be effective. Surface-enhanced Raman spectroscopy (SERS), especially when incorporated with nanotechnology, possesses the capability to identify chemical fingerprints with an extremely high level of sensitivity, even in complicated biological contexts. (Shi et al., 2023). It operates in a label-free, minimally invasive, and rapid fashion, making it a compelling candidate for next-generation lung cancer diagnostics.

3. ROLE OF GOLD/SILVER NANOSTRUCTURES IN ENHANCING SERS SIGNALS

Mechanism of SERS Enhancement

The primary source of the increase of Raman signals in surface-enhanced Raman spectroscopy (SERS) is the phenomenon of localized surface plasmon resonance (LSPR). When light with a certain wavelength strikes metal nanostructures, usually gold or silver, the conduction electrons in the nanostructures oscillate collectively, a phenomenon known as localized surface plasmon resonance (LSPR) (Zhao et al., 2023). As a result of this oscillation, extremely strong electromagnetic fields are produced in the vicinity of the surface of the nanoparticle, particularly at sharp edges or junctions, which are sometimes referred to as "hot spots." These electromagnetic fields dramatically enhance the Raman signals of molecules in close proximity.

Due to the fact that they have the requisite optical characteristics to allow plasmonic oscillations within the visible and near-infrared range, gold and silver nanostructures are appropriate for this particular application. These "hot spots" can enhance Raman signal intensity by several orders of magnitude, often up to 10^8 or even 10^{10} times, depending on the nanoparticle geometry and surface properties (Chen et al., 2021). This makes SERS one of the most sensitive label-free molecular detection techniques available.

Types of Nanostructures Reviewed

A variety of gold and silver nanostructures have been manufactured and investigated in order to determine their surface-enhanced Raman spectroscopy (SERS) performance in biological diagnostics. Examples of gold nanostructures are nanospheres, nanorods, nanostars, and nanoshells. Gold nanostars, with their multi-branched structure, are particularly useful because the structure provides several hot spots for increased signal output (Chen et al., 2021).

Silver nanostructures, on the other hand, include nanocubes, nanoprisms, and core–shell particles. These geometries are capable of generating stronger electromagnetic fields than gold due to their higher intrinsic plasmonic activity (Rahman and Gupta, 2020). Core–shell combinations, such as Au@Ag (gold core, silver shell), utilize the stability of gold and the high enhancement factor of silver to form hybrid platforms optimized for SERS (Zhao et al., 2023).

Review of Secondary Studies

In a study by Chen et al. (2021), When it came to the detection of carcinoembryonic antigen (CEA), a biomarker associated with lung cancer, gold nanostars exhibited a considerably larger SERS enhancement than gold nanospheres. Because of their distinctive shape, the number of active plasmonic sites per particle was enhanced.

Rahman and Gupta (2020) observed that silver nanoprisms provided even greater signal enhancement than gold counterparts. However, they also emphasized the lower biocompatibility and higher susceptibility to oxidation of silver, which limits its utility in clinical applications.

Zhao et al. (2023) explored the use of core–shell Au@Ag nanostructures in multiplexed SERS assays for cancer biomarker detection. Their findings demonstrated significant enhancement, high repeatability, and structural stability, which makes these particles appropriate for advanced diagnostics.

Benefits of Gold vs. Silver Nanoparticles

Due to their exceptional biocompatibility, colloidal stability, and chemical inertness, gold nanoparticles are the material of choice for biomedical applications. They have the ability to be readily functionalized with ligands, antibodies, or PEGylated compounds in order to target

certain biomarkers. When it comes to signal augmentation, silver nanoparticles are more powerful, but they are also more chemically reactive and more susceptible to oxidation, all of which can negatively impact how well they work in biological contexts (Rahman and Gupta, 2020).

Theoretical Comparison

Theoretical evaluations of enhancement factor (EF) ranges for different nanostructures provide comparative insights. Gold nanospheres typically offer EF values between 10^4 and 10^5, while gold nanostars extend that to the 10^6 to 10^8 range. Silver nanoprisms can achieve EFs of 10^7 to 10^9. Hybrid structures such as Au@Ag core–shells have reached enhancement values close to 10^8 to 10^{10}.

Their chemical instability and probable cytotoxicity are factors that must be taken into consideration, despite the fact that silver and hybrid nanoparticles provide outstanding sensitivity. Despite being somewhat less sensitive, gold-based devices are frequently more appropriate for clinical diagnostics as a result of their inert and biocompatible characteristics. It is essential to take this trade-off between enhancement and biological compatibility into consideration when developing effective diagnostic systems based on surface-enhanced Raman spectroscopy (SERS).

4. THEORETICAL MODELING OF OPTIMAL NANO-SERS SYSTEMS

Essential Criteria for Model Development

For optimal nano-SERS systems intended for early lung cancer diagnosis, several criteria must be met:

- Signal uniformity, meaning the SERS substrate must produce consistent enhancement across its surface, avoiding “hot spot” clustering only in small patches.
- Reproducibility, so that different batches of the same substrate yield similar enhancement factors under the same conditions.
- Scalability, meaning the fabrication method should be amenable to large-scale production without losing performance.

- Biomarker specificity, ensuring that the surface functionalization binds intended lung cancer biomarkers (such as EGFR, CEA, CYFRA 21-1) with high specificity and low cross-reactivity.
- Low cytotoxicity, so that any gold/silver nanostructures used in bodily fluids or close to tissues do not induce undue adverse effects.

Proposed Theoretical Framework Components

The following framework components are recommended for the purpose of creating nano SERS systems that meet the aforementioned criteria:

- **Core Material Selection**: Make use of the chemical stability and biocompatibility of gold by utilizing it as a core material; it is possible to optionally coat or shell the gold with silver or to utilize silver in proximity to the core in order to increase sensitivity. The core made of gold helps to prevent oxidation and cytotoxicity, while silver provides better amplification.
- **Shape Optimization**: Instead of using basic spherical shapes, consider using nanostructures that are rod-shaped or star-shaped (nanostars). Sharp points and edges are more likely to be found on rods and stars, which generate more "hot spots." Electromagnetic enhancement can occur with greater concentration when the tips are longer and the spikes are sharper.
- **Surface Functionalization**: Attach ligands, aptamers, or antibodies that are specific to biomarkers of lung cancer, such as epidermal growth factor receptor (EGFR), cytokeratin fragments (CYFRA 21 1), and carcinoembryonic antigen (CEA). It is of the utmost importance that the plasmonic characteristics are preserved during the functionalization process. Additionally, it must be ensured that there is no blockage of hot spots and that substantial steric hindrances are not created.

Review of Modeling Approaches

Some existing studies have done modeling or simulation of SERS substrates to optimize these features:

- A numerical study on gold nanostars (by Chung & Lee, 2022) varied parameters like spike number, spike tip angle, and spike-to-core ratio to determine how geometry affects field enhancement. They used finite-difference time-domain (FDTD) simulations to map how shapes influence both far-field and near-field spectral responses, finding that there is optimal geometry for generating maximum enhancement at given wavelengths (Chung & Lee, 2022).

- Recent reviews have emphasized advanced fabrication methods and substrate design features to improve uniformity and reproducibility, including multilayered SERS surfaces, hierarchical nanostructures, and plasmon coupled core-shell or multi-metallic constructs. These designs are aimed at amplifying signal without compromising stability or specificity.

- Studies leveraging FDTD simulations have modeled electromagnetic field distribution in rod-, star-, core-shell-, and tip-rich geometries. For example, mapping of "hot spot" locations (at tip, edges, in narrow inter-particle gaps) shows that tiny gaps (few nanometers) between particles or spikes contribute disproportionately to enhancement.

Challenges in Translation

Designing theoretically optimal nano-SERS systems is only half the job; translating into usable diagnostic tools involves issues such as:

- **Uniform fabrication at scale:** laboratory-scale nanostars or rods are often hand-made or in small batches; scaling up while maintaining shape fidelity and hot-spot distribution is difficult.

- **Biological noise in complex samples:** body fluids like serum, sputum, or exhaled breath contain many molecules that can non-specifically adsorb, quench signals, or introduce background noise, reducing specificity.

- **Integration with machine learning for signal interpretation:** raw SERS spectra are complex; distinguishing real biomarker signals from background or noise requires sophisticated algorithms, pattern recognition, and often large labeled datasets, which may not always be available.

Roadmap toward Clinical Translation

Below is a proposed roadmap outlining stages toward moving from theory to clinical utility:

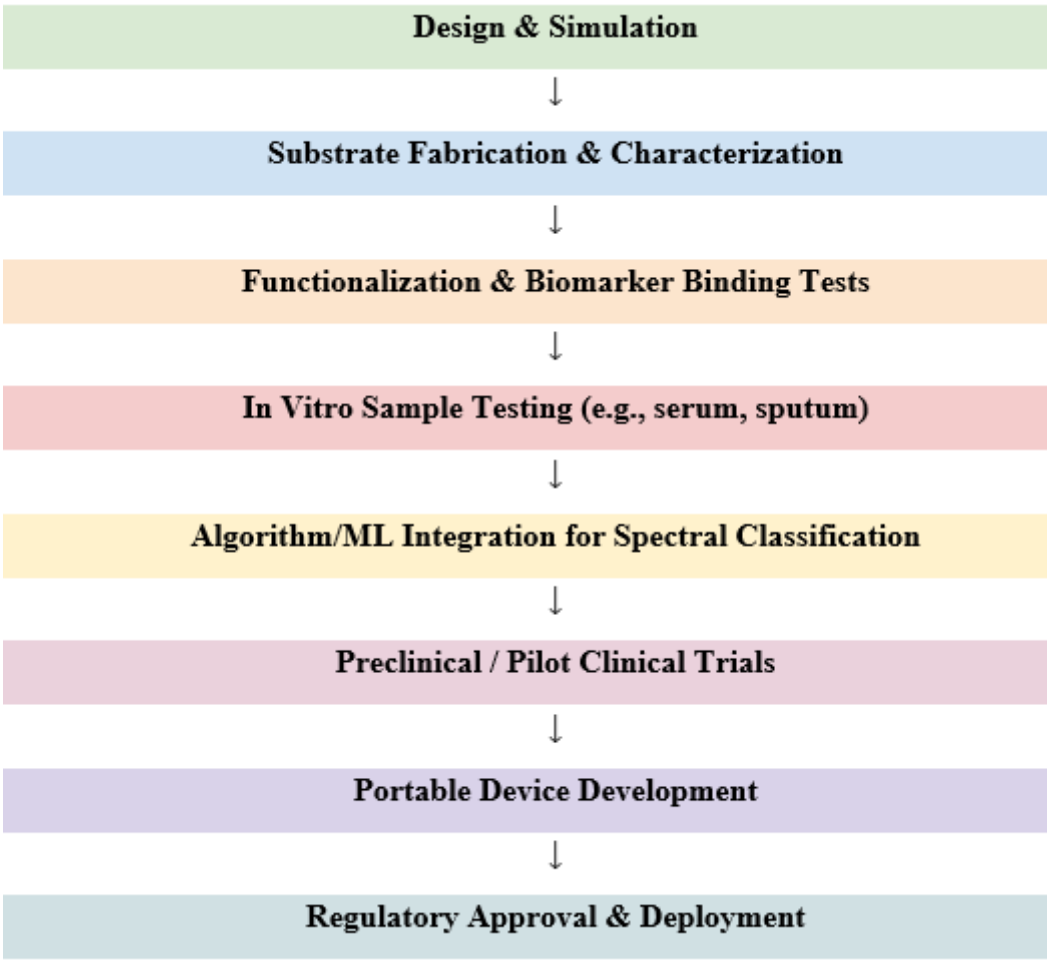

Figure 1: Proposed workflow for developing nano-SERS systems from design through clinical deployment. Each stage includes feedback loops for optimization

Collaboration across multiple disciplines is critical in this roadmap. For the design of nanostructures, physicists are required; materials scientists are needed for fabrication; biochemists and molecular biologists are needed for biomarker specificity; data scientists and machine learning experts are needed for signal processing; and clinicians are needed for real sample validation. In order to enable screening that is noninvasive, early attention should be made on platforms for the detection of several biomarkers and on the mobility of equipment (for example, breath analyzers or point-of-care strips).

5. CONCLUSION AND RECOMMENDATIONS

Conclusion

The extensive theoretical assessment that was undertaken in this work confirmed again that the combination of nanotechnology with Surface-Enhanced Raman Spectroscopy (SERS) showed great potential for increasing early lung cancer diagnosis. The findings underscored the important need for diagnostic techniques that are extremely sensitive, non-invasive, and repeatable, especially in light of the increasing burden of late-stage lung cancer diagnosis. When intervention is delayed, patient survival is considerably affected.

It was apparent from the theme analysis of the secondary literature that nanostructures made of gold and silver played a critical role in increasing the signal from surface-enhanced Raman spectroscopy (SERS). Biomarker targeting was made simple by the fact that gold nanostructures are easily functionalized with ligands and aptamers. Additionally, gold nanostructures exhibited excellent biocompatibility. On the other hand, silver nanostructures provided excellent augmentation in electromagnetic field intensities, but they were frequently limited by their instability and biological reactivity. In the development of actual surface-enhanced Raman scattering (SERS)-based biosensors, the maintenance of a balance between signal amplification and cytotoxicity was found to be a fundamental design problem.

Additionally, the study discovered that clinical translation continued to be a bottleneck, despite the fact that theoretical frameworks and computational modeling provided unique insights into nanostructure shape optimization and SERS response prediction. There were several obstacles that were mentioned in the majority of the papers that were evaluated. In particular, these studies noted issues such as uniformity in the synthesis of nanoparticles, biological noise in real samples that caused interference, and the repeatability of test batches.

Overall, the study made a convincing argument that nano-enabled SERS systems are an ideal candidate for the next generation of diagnostic tools, particularly for the identification of biomarkers present in bodily fluids, such as blood, breath, or sputum, at low concentrations. Successful implementation, on the other hand, was contingent on the requirement for integration with regulatory bodies, clinical validation processes, and interdisciplinary cooperation.

Recommendations

1. **Hybrid Nanostructure Development:** Future nano-SERS systems ought to give precedence to hybrid materials like gold-silver core–shell nanoparticles. This method provides a synergistic balance between the high enhancement factor of silver and the biological stability of gold. The optimization of these nanocomposites can aid in reducing cytotoxicity while preserving signal integrity at the same time.

2. **Standardization Protocols:** Standardizing the methods for surface modification, nanoparticle production, and biofunctionalization is something that is greatly needed at this time. These kinds of standards will improve the repeatability of research across various labs and make the transfer into clinical pilot trials less complicated.

3. **Multi-Biomarker Platforms:** SERS systems ought to go past the point of single-analyte detection and develop into diagnostic instruments that are able to identify several biomarkers. Multiplexed SERS (Surface-enhanced Raman scattering) tags can be designed to simultaneously identify several indicators of lung cancer, which would improve the accuracy of diagnoses and decrease the number of false negatives.

4. **Integration with AI:** In order to increase the classification accuracy between samples that are malignant and those that are not malignant, machine learning and artificial intelligence has to be utilized for the interpretation of complicated SERS spectra. Predictive algorithms are another way that pattern recognition models might improve early detection.

5. **Clinical Collaboration:** It is imperative that physicists, oncologists, material scientists, and bioengineers work together in strong relationships. Hospitals should be included early on in the process of establishing the clinical feasibility of SERS-based nano-diagnostic systems, particularly in tertiary care and early screening programs.

6. **Policy Inclusion:** Last but not least, public health policies and cancer screening campaigns need to start taking into consideration next-generation diagnostic techniques, such as nano-SERS systems. Long-term acceptance will be made possible by the promotion of financing, approval processes, and inclusion in medical recommendations.

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