IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

# PLASMONICS AND ITS APPLICATIONS

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***Abstract:*** In recent years, plasmonics has emerged as a revolutionary field of study with immense potential for various applications. This article explores the fascinating world of plasmonics and delves into its wide-ranging applications. Plasmonics is the study of the interaction between light and free electrons in metallic nanostructures, giving rise to surface plasmon polaritons (SPPs). These SPPs have unique properties that allow for the manipulation and control of light at the nanoscale. By harnessing these properties, plasmonics holds promise in fields such as sensing and biomedical applications.

***IndexTerms*** **– Plasmonics, Applications, Surface plasmons**

## INTRODUCTION

Plasmonics is an entirely novel area of expertise that has sprouted owing to noble metal nanostructures capacity to regulate illumination at the nanoscale. These nanostructures have broad range of usage in chemical and biological sensing, medicines, photothermal therapeutics, food sciences, environmental sciences and solar energy. Nowadays, It is feasible to produce metal particles with heterogeneous compositions, which comprise plasmonic materials, and control their dimensions, form, besides arrangement. [1]First discovered as surface plasmon polaritons in the 1950s marked plasmonics' inception.Plasmonics, also called as nanoplasmonics, is a rather young area of study within the domains in nanophotonics along with nanooptics. The study of electron oscillations in metallic nanostructures and nanoparticles (NPs) is the core focus of plasmonics.[2]When electromagnetic radiation is applied to a metal surface, conduction electrons on the surface oscillate coherently, creating surface plasmons (SPs) at the metal-dielectric contact.The field of plasmonics is likewise quite busy because of recent developments in nanofabrication techniques.Metal nanostructures made up of nanoparticles (NPs), nanoholes, and other elements with carefully regulated sizes, shapes, and/or spacings have been made possible by these techniques.[3]A major advancement in our comprehension of the science underpinning plasmonics is made possible by the combination of nanometer-scale production processes and increasingly complex numerical modeling capabilities. [4] Surface plasmon resonance is the collective oscillation of free electrons in a plasmonic nanoparticle at a resonant frequency caused by an alternating electric field under light irradiation. Calculations and tests have demonstrated that theparticle shape, which controls the distribution and polarisation of free electrons on the surface, has an impact on the resonance's frequency and amplitude. Thus, the most effective way to modify and fine-tune an optical resonance property of a plasmonic nanoparticle is to change its shape.[5]The field of optical sensors has experienced tremendous growth and widespread applications in recent years. Surface plasmon resonance has established itself as an immensely acclaimed and influential optical sensing tool with quintessential applications in life sciences, environmental monitoring, clinical diagnosis, pharmaceutical developments, and ensuring food safety.Surface plasmon resonance (SPR)-based optical sensorsHave become one of the most frequently used types of sensors. They are extremely useful and adaptable, offeringA broad spectrum of commercial and research opportunities in the chemical and biological sciences. [6]

This review article includes various applications like Detection of various viruses, Detection of antibodies, Biosensors, Plasmonic photothermal monitoring, Monitoring haemoglobin levels in blood, DNA based plasmonic structures, In pharmaceutical analysis, Diagnosis of dengue virus, Detection of cancer, Detection of cyanide, Plasmonic Nanostructures in Sensor

Technologies and Chemical, Imaging, Detecting and differentiating neurotransmitters, Sum-Frequency Generation (SFG) spectroscopy, Treatment of cancer and respiratory diseases, Microorganism detection, Surface-enhanced Raman spectrum (SERS), Particle-to-particle integrating-based colorimetric sensing, Utilizing of Rayleigh scattering for imaging and sensing , Label-Free Optical Authentication Utilising Refractive Index alterations, Detection of Alzheimer's, Detection of PCOS, Quantitative analysis of glucose, Detection of Parkinson's disease, Biodiagnostics, Plasmonics for health.

**APPLICATIONS**

**1) RECOGNITION OF NUMEROUS VIRUSES:**

Plasmonics offers an appropriate platform for quick and affordable detection in early stage, because it is a non-invasive, sensitive, label-free, real-time,highly resolved approach. Plasmonics is a real-time biomolecular interaction Technology for detection which can recognize an extensive range of analytes varying molecular weights and binding affinities. Conventional surface plasmon resonance(SPR) method uses a thin metallic (usually Au) film to screen compounds by immobilising a specified protein, or ligand, on the sensor chip's surface and observing how it binds to the target compounds. This method is used in the Recognition of numerous viruses including Coronaviridae Family, HIV, Influenza, Hepatitis, Zika, Rabies, Ebola, Norovirus and Dengue besides 2 common genital virus of HPV and HSV.[7]
Plasmonic-based biosensors convey immense potential for viral detection. The general merits include swiftly sampling, lower LOD, an expansive linear range, robust sensitivity, and high selectivity. Specific sensing based on plasmonic platforms—such as SPR, LSPR, SEF, SERS, and SEIRA—has been found to feature a multitude of attributes that make it compatible with an array of applications. However, the utilising of plasmonic-based biosensors in point-of-care (POC) devices to detect viral infections is currently in its earliest phases. More research and development must be done in order to ready this sensor technology for commercialization and practical usage. Color-based sensors that react to questions that are either yes or no utilizing LSPR are commercially available. However, quantitative sensors capable of detecting even lower accumulations have yet to hit the market. The explanation behind this is that concentrated binding approaches can only be refined when trying to choose the molecule of interest from many of the molecules in the sample. However, these reported plasmon-based sensors retain good sensitivity with a rapid reaction time; however, when compared to the PCR approach, plasmonic sensors have a forum for superior throughput. Plasmonics serves as vital in the development of SARS-CoV-2 sensors for swiftly, effectively, and cost-effective detection. The most efficient SARS-CoV-2 detection method tends to use real-time PCR, which has 100% selectivity and is the most occasionally adopted clinical diagnosis methodical approach.[8]

**2) DETECTION OF ANTIBODIES:**

Significant benefits over classical ELISA exist for SPR-based immunoassay, which may enable robust and highly reliable monitoring of serum accumulations of infliximab and other therapeutic antibodies. Therapeutic drug monitoring would be considerably more applicable and beneficial if SPR-based devices were used for point-of-care analysis, which occurs right before a clinical decision. These devices are dependable, simple, quick, and affordable (TDM). Data from these newly created, reasonably priced optical fiber-based SPR sensors (SPR-POF) enables the fabrication of a small, miniaturized remote sensing system. An anti-infliximab antibody adhered on the outer layers of the SPR-POF sensor is bound by infliximab. These proof-of-principle investigations open the door for additional technical advancements by proving that the suggested SPR-POF platform is feasible for the precise detection of infliximab in buffer and human serum.[9]

**3) BIOSENSORS:**

Optical biosensors, mostly based on nanoplasmonic components are currently accessible to disease diagnostic research and therapeutic follow-up at the point of care (POC). In tiny magnetic nano particles (MNPs), the collision of the electromagnetic field with an adequate wavelength to conductive electrons exerts a strong force on them. It generates a charge on the nanoparticles surface by transferring the electrons in transmission from their stable locations, consequently the MNPs' surface becomes polarized,and electrons are excited. The excited MNPs exhibit resonance oscillation and form a localized surface plasmon resonance (LSPR) phenomenon in an extensive range. wavelengths from visible to infrared, depending on the NPs' size, shape, structure (solid or hollow), interparticle distance, and embedding refractive index, allowing them to detect minor changes in their local medium. LSPR is a very sensitive optical sensing device capable of detecting tiny fluctuations in a metal-dielectric interface's effective refractive index in real time. The selection of plasmonic materials as a substance to create surface plasmon resonance (SPR) or LSPR is crucial in biosensing.[10]

**4) PLASMONIC PHOTOTHERMAL THERAPY:**

In prior few decades, there has emerged some usage of plasmonic photo-thermal therapy (PPTT), a nonsurgical therapeutic methodin which photon energy can be transformed into heat adequate to blast cancer cells. Considering natural tissue absorbents offer low absorption results, manmade natural pigment molecules such as indocyanine green, naphthalocyanines, and porphyrins accompanied by transition metals can be applied externally to boost the photothermal effect at tumor destinations. Plasmonic photothermal therapy (PPTT) signifies a sort of photothermal therapy triggered by plasmonic gold nanoparticles. Cells harboring

breast cancer have been bombarded with cwNIR (continuous-wave near infrared) light at an intensity of 35 w/cm2 for 7 minutes in the instance of polyethylene glycol (PEG)-coated gold nanoshells (Au NSs), and the cells were destroyed. The cancinoma cells were eliminated without harming the healthy cells following exposure to a concentrated NIR light beam.[11]

**5) MONITORING HAEMOGLOBIN LEVELS IN HUMAN BLOOD:**

The introduction of a surface Plasmon resonance-based biosensor design is intended to track the levels of hemoglobin in human blood. The Kretschmann structure, upon which the design is based, comprises an SF10 prism and is enhanced in sensitivity by layers of metal, graphene, and metal dichalcogenide. The 632.8 nm-wavelength He-Ne laser is the optical source under consideration. Based on the refractive index of human blood, this structure is used to compute the reflection coefficients that correlate with the healthy range of hemoglobin concentration in human blood. This sensor is utilized to measure the fluctuation of human blood in a healthy state of blood iron for men and women between the ages of 20 and 80 years. First, its sensitivity is tuned using a sample of water. The optimized structure's reflection coefficients for a healthy range of hemoglobin accumulations for adult males vary from 0.6805 (a.u.) to 0.7067 (a.u.), and for adult females, they range from 0.6547 (a.u.) to 0.6583 (a.u.), according to the results. Lower values correspond to hemoglobin and iron. Measurements of blood plasma health, drinking water quality, and food quality control can all benefit from the utilities of this design.[12]

**6) DNA-BASED PLASMONIC NANOSTRUCTURES:**

The willingness to accurately manipulate nanoparticle arrangement is a necessity for building plasmonic, molecule-like frameworks. DNA can be utilized as a template for the spatial placement of functionalized nanoparticles and/or as a ligand (via monofunctionalization and anisotropic functionalization). Thus far, abroad array of options of plasmonic additionally, substance have been proved to be effective spacers, linkers, and templates for helping to arrange metallic nanoparticles into highly ordered plasmonic polymers and crystals. DNA may be used as a framework to create 1D regularly spaced nanoparticle chains, or "plasmonic polymers," with branching, helical, and linear topologies. By using specialised base pairing recognition or just electrostatic interactions with DNA templates, nanoparticles may be arranged into polymers. Usually, DNA tile-based or origami templates are used to create ordered 2D arrays of metallic nanoparticles, onto which a DNA-encoded nanoparticle can hybridize.Crystals of 3D plasmonic nanoparticles furthermore been successfully constructed using DNA molecules. Plasmonic nanoparticles may self-organize into three-dimensional crystals featuring different lattice topologies that are reversible with temperature changes, all by means of programming DNA sequences. The fast advancement of DNA-based plasmonic nanostructures, resulting from the ongoing integration of nanoparticle synthesis, surface chemistry, DNA nanotechnology, and lithography, may soon lead to real-world applications such as sensing, waveguiding, and energy harvesting. [13]

**7) IN PHARMACEUTICAL ANALYSIS:**

Surface plasmon resonance (SPR) and localized surface plasmon resonance (LSPR) biosensors have aided the drug innovative process for reasons they can measure incredibly small changes in surface refractive index (RI), binding equilibrium, and kinetics.(L)SPR biosensors can be used in almost every stage of pharmaceutical analysis that calls for kinetic profile, target identification, or characterization because they can monitor nearly any kind of molecular interactions of various biological molecules, such as serum proteins, oligomers, antibodies, and enzymes. Using surface plasmon resonance (SPR) to measure binding kinetics is crucial for determining the duration of action, clinical benefit, and therapeutic differentiation of a candidate medicine from two or more comparable compounds of drug. Applications of SPR include protein activity and stability studies in the manufacturing of biopharmaceuticals, besides the fabrication of novel biotherapeutics and drug discovery research.[14]

**8) DIAGNOSIS OF DENGUE VIRUS:**

Using the dengue viral antigen as a sensing element, an SPR-based immunosensor was developed for a label-free, real-time test for the purpose of recognize the dengue virus infection. The dengue virus antigen paired with serum albumin from bovineis covalently immobilised on a gold sensor device via activated self-assembled monolayer (SAM) of 11-mercaptoundecanoic acid, byamide integrating. Atomic force microscopy was utilized to record the biosensor's surface morphology. Increase in resonance anglein direct immunoassays were utilized in order to figure out if dengue virus-specific IgM antibodies in dengue-positive sera. The surface plasmon resonance (SPR)-based immunoassay has enormous potential in the biomedical field, including epitome mapping,drug discovery, bio-interaction studies, Alzheimer's disease biomarker development, acute myocardial infarctions, and monitoring clinically significant analytes like cholesterol and dopamine. This is because it combines the selectivity of molecular acknowledgmentof biomolecules with the high sensitivity of the SPR signal transducer. [15]

**9) DETECTION OF CANCER:**

A biosensor platform depends on surface plasmon resonance (SPR) is utilized to detect carcinoembryonic antigen **(**CEA), which is a key tumor indicator for the colon and lungs carcinomas. The creation and enhancement of the CEA immunoassay on the SPR gold sensorsurface resulted in great sensitivity for real-time illness detection**.** Low threshold for detection CEA was obtained, whichreflects the crucial CEA level in non-smokers, by applying label-free real-time biosensor technology. This will assist in locating

potential cancer patients. Without requiring invasive surgical procedures, the approach demonstrates a viable technology of the next decade for the identification of cancer at as wiftly stage. [16]

**10) DETECTION OF CYANIDE:**

Cyanide detection is critical in spite of its fatal toxicity in physiological systems furthermore its environmental implications. For the purpose of cyanide detection, a highly accurate and precise probe has been created using plasmonic Ag/Fe3O4 nanoparticles (NPs) with an extraordinarily low threshold for detection of ng per milliliter. The approach is predicated on the substantial amplification of scattered light from plasmonic nanoparticles while concurrently quenching cyanide fluorescence. In this study, Ag/Fe3O4 NPs were easily produced utilizing a green preparation approach, and the NPs were then characterized by powder XRD, UV-Visible absorption spectroscopy, transmission electron microscopy (TEM), and energy dispersive X-ray spectroscopy (EDX).A combination of absorption, Rayleigh, and fluorescence properties were employed to detect cyanide in real samples at lethal accumulations ranging from 1.0 nM to 160 mM. Other advantages of the novel technique include little pH dependence, fast response time, a low detection limit (as low as 1 nM) and high sensitivity, good precision and selectivity in the presence of other competitive environmental ions, and inexpensive preparation costs. The sensor demonstrated improved applicability in real samples and can be utilized to detect fatal cyanide in practical water systems.[17]

**11) PLASMONIC NANOSTRUCTURES IN SENSOR TECHNOLOGIES AND CHEMICAL IMAGING:**

11.1. COLORIMETRIC DETECTION:

An experiment employs modified oligonucleotides Au NPs that show substantial red shifts when accumulated when there is a corresponding nucleotide. The shift in hue in this scenario is caused by both particle-particle plasmonic interaction and aggregate scattering and thus performs as a "litmus test" for detecting nucleic acid ambitions.

11.2. SPR SPECTROSCOPY:

Utilizing this surface-sensitive strategy, fluctuations in the refractive index of SPPs propagating on metal-dielectric surfaces can be observed through the evanescent field. Variations in the optical index affect the plasmon resonance record. These adjustments can provide empirical information on the binding event by being gauged as fluctuations in exertion, spectrum, or angle. SPR spectroscopy's limitations in regards to accuracy and detection can be assessed by means of small distinctions in refractive index, which contribute to the binding of low-molecular-weight analytes or a tiny quantity of a more expansive analyte. SPR spectroscopy and imaging are two typical label-free optical screening methods that track surface adsorption events in real time, which means they simultaneously make use of this attribute. These approaches are utilised to pinpoint changes in the observed SPR resonance, which might have been recognized through angular, wavelength, or intensity measurements, owing to alterations at a flat surface's dielectric environment or on an ongoing schedule patterned noble-metal report. The thermodynamic and kinetic data for an assortment of range of molecule-binding events, particular those involving biomolecular targets, can possibly be analyzed by this well-established approach.

11.3. PLASMON-ENHANCED FLUORESCENCE:

It is an even more cutting-edge technology that can improve sensitivity and detection limitations. This capacity entails incorporating the measurement into a device form factor that may use the amplified electrical fields associated with surface plasmons.[18]

**12) DETECTING AND DIFFERENTIATING NEUROTRANSMITTERS:**

Detecting neurotransmitters high effectiveness and selectivity are essential for comprehending their respective responsibilities. in biological processes. UV plasmonic-engineered native fluorescence is a new way to identify neurotransmitters. The natural fluorescence of three monoamine neurotransmitters, dopamine, norepinephrine, and 3,4-dihydroxyphenylacetic acid, is evaluated on a 30 nm-thick Al thin film and an Al hole array with a hole spacing of 300 nm. The three compounds showed a net fluorescence increase and improved total photon yields of 50× and 60×, correspondingly, rendering them appropriate for sensitive neurotransmitter detection. Aluminum hole arrays show a 1.5–1.7x a decline in the dominant photon bleaching rate compared to aluminum-thin film substrates. The photobleaching rates of the native fluorescence of DA, NE, and DOPAC were discovered to be very sensitive to their molecular structures and can be further modified using UV plasmonic substrates. [19]

**13) SUM-FREQUENCY GENERATION (SFG) SPECTROSCOPY:**

The field of non-linear SFG spectroscopy coupled to plasmonic nanomaterials has matured enough to be deemed a potential study plasmonics. The interest in using SFG (Sum-Frequency Generation) spectroscopy as a complementary tool to surface-enhanced Raman spectroscopy to probe the surface chemistry of metallic nanoparticles is demonstrated by exploiting the optical amplification caused by integrating to the localised surface plasmon resonance. This spectroscopy is mostly focused on chemical and biological difficulties, such as recognition procedures that lead to monitored drug distribution for medical purposes. It has become a standard

optical examination in many research centers throughout the world.

## 14) TREATMENT OF CANCER AND RESPIRATORY DISEASES:

Cancer is the new pandemic and the biggest cause of death in the modern era. Cancers of the mouth, stomach, lungs, ovaries, skin, and blood are becoming more common. Several factors, including the environment, diet, lifestyle, and smoking, can cause cancer. Cancer detection in the initial phases. is critical because it saves lives with current treatments. Imaging techniques such as X-ray, computed tomography scan (CT), positron emission tomography (PET), ultrasound, and magnetic resonance imaging (MRI) are commonly used to diagnose cancer. These are also expensive, require complex instruments, take time, and are frequently performed with numerous tests to eliminate ambiguity. Plasmonic biosensing has become more widely recognized currently for cancer diagnosis and treatment. SERS permits liquid biopsy by utilizing urine, saliva, and serum, making it less expensive and allowing for more frequent sample compared to existing tissue-biopsy procedures, which are typically damaging. SERS is used to study a variety of cancer biomarkers, including miRNA (microRNA), proteins, exosomes, circulating tumor DNA (ctDNA), genes, peptides, and blood plasma. SERS tags that bind selectively to the targets being studied are commonly employed to analyze cancer samples.

### 14.1. LUNG CANCER:

Lung cancer is the most lethal and frequently diagnosed cancer, with an estimated 2.89 million cases by 2030. The primary culprits include smoking, carcinogenic chemicals in the environment, and lifestyle. Lung cancer is classified into two types: non-small cell (NSCLC) and small cell lung cancer (SCLC). SERS analysis has proven successful in detecting both forms of lung cancer, with the possibility for point-of-care and quick testing. Studies have created lateral-flow-assay-based SERS substrates for the fast detection and quantification of lung cancer biomarkers such miRNA and ctDNA. SERS-based detection has also been accomplished utilizing asymmetric polymerase chain reaction (PCR) and a combination of asymmetric PCA (Principal component analysis) and support vector machines (SVMs). Lung-cancer biomarkers (aldehydes) and cells were quickly identified utilizing renewable porous CuFeSe2/Au nanostructures, whereas volatile organic chemicals were detected using ZIF-8-coated gold super particles. The SERS-based classification of lung cancer and normal samples attained 100% sensitivity and 90% specificity, respectively. SERS-based detection has relied on a variety of biomarkers, including common protein carcinoembryonic antigen (CEA) and a-fetoprotein (AFP). SERS analysis of saliva samples has furthermore been employed to distinguish between healthy and malignant samples, with tact of 95% and 97%.

### 14.2. BREAST CANCER:

Breast cancer, the second biggest cause of mortality, is frequently detected via mammography, ultrasonography, MRI, or biopsy. SERS, an ultrasound test, has been used to investigate drug carrier mechanisms. Xiao et al. created a gold nanorod-based SERS technique for breast cancer diagnosis that uses epidermal growth factor as a biomarker. The technique can detect the spatial and temporal distribution of breast cancer cells by utilizing biomarkers such as sialic acid and phenyboronic acid-based nanoprobes. The identification of miRNAs in breast cancer cells was accomplished with great sensitivity utilizing a hybrid SERS substrate. Other research have used SERS and electrochemical biosensors to monitor treatment response in breast cancer cells, besides gold nano-stars with unique affinity for breast cancer cells. Gold nanoparticles were used to image cancer cells using SERS, while gold nanorods and bipyramids were used for photothermal therapy and SERS-based detection. A three-in-one technique integrating photoacoustic imaging, thermos surgery, and SERS has been created to treat persistent microtumors in breast cancer.

### 14.3 SARS COV2 AND RESPIRATORY DISEASES:

The epidemic has prompted swift identification, detection, and quarantine of affected individuals. PCR, the leading technology for identifying SARS-CoV, depends on studying the virus's genetic content yet the price tags is enormous. and time-consuming. SERS, a quick, adaptable, and cost-effective approach for detecting respiratory viruses, employs an assortment of nanomaterials. SERS has likewise been assigned to detect other respiratory infections, including H1N1, H7N9, H3N2, and H5N1, besides coronaviruses such as MERS-CoV. Machine learning algorithms are frequently utilized to detect patterns that are not evident to the naked eye. SERS has also enabled the resolve of viral load, which is pertinent to assess infection severity. Gold nanoparticles functionalized with a specific enzyme were utilized to detect the S protein produced by COVID-19 viruses using SERS-based sensing in water. A lateral-flow immunoassay-based SERS was proposed in order to get the quantitative recognition of SARS-CoV-2. Similar research was conducted on the trace detection of SARS-CoV-2 antibodies and spike proteins.

### 14.4MISCELLANEOUS:

SERS has been widely utilized to detect different malignancies, such as gastric, oral, liver, ovarian, and prostate cancer. Gastric cancer has been diagnosed utilizing several plasmonic materials by evaluating SERS spectra from serum samples, blood plasma, exosomes, extracellular vesicles, telomerase, saliva, and ctDNA. In a groundbreaking study, a breath analysis using SERS was used to identify distinct stages of stomach cancer by examining Raman bands.

## 15) MICROORGANISM DETECTION:

Bacteria are living cells that exist in a variety of habitats, including water, food, soil, air, and the human body. Bacteria detection is critical for both public health and bioremediation. Traditional procedures like as PCR, plate culture, and flow cytometry are time-consuming, taking 2 to 3 days to arrive at findings. SERS-based bacteria sensing is frequently employed because to its specificity,

sensitivity, speed, and water compatibility. SERS can discriminate between living and dead bacteria cells. Wang et al. utilized magnetic nanoparticles to detect S. aureus, and SERS substrates with metal phenolic networks were constructed to detect both E. coli and S. aureus. SERS-based immunoassays have been utilized to identify many bacteria species concurrently with high sensitivity and quantitative accuracy. A ceramic-filter-based SERS substrate containing metal nanoparticles was employed to detect E. coli and Shewanella putrefaciens. SERS, paired with deep learning algorithms, has been used to accurately identify Staphylococcus aureus, with an accuracy of around 98%.

**16) SURFACE-ENHANCED RAMAN SPECTROSCOPY (SERS):**

The tendency to detect traces, paving the way for early detection, cost-effectiveness, and swift diagnosis, considers surface-enhanced Raman spectroscopy/scattering (SERS) an intriguing method for disease diagnosis. SERS's sensitivity was proven when it was enabled to locate a single bacterial cell under optimal circumstances. SERS may be utilized to identify disease biomarkers in flammable substances and gases, besides in an array of bio-fluids such blood, plasma, saliva, and urine. SERS does not need ongoing procedures for the acquisition of disease biomarkers, contrary to many commercial approaches. It is also reagent free. Using SERS for tumor identification, it has also been possible to differentiate between malignant and normal samples—including liquids and cells—besides different cancer stages. When juxtaposed with the prevailing cancer screening operations, these approaches are more affordable, quicker, and more sensitive. SERS has been frequently used in response to the pandemic scenario to discover the new COVID-19 virus and track the effectiveness of vaccinations. SERS's the relevance in homeland security has also been boosted by its widespread usage in the detection of many different nerve agents and other bio-warfare tools. With numerous lateral flow and point-of-care devices created in response to the pandemic and the detection of other diseases with performance on par with current commercial techniques, the commercialization of SERS is right now under progress.For instance, it has been demonstrated that SERS allows multiplexing with a very little sample amount and performs better in cancer detection than commercial enzyme-linked immunosorbent assay (ELISA) test kits. SERS was found to perform comparably well in a recent study when it came to quantifying glucose in blood sugar when compared to a clinically accessible approach. For the detection of covid, it was discovered that SERS is 16–32 times more sensitive than the commercial lateral flow assay and >400 times more sensitive than the ELISA using the same reagents. A laser source, a probe for excitation and signal collection, and a detection system with a spectrometer make up the main parts of a Raman system. Advancements in miniaturization and cost reduction on all fronts have made it possible for SERS-based detection to be comprehensively used with portable devices.[21]

**17) PARTICLE-TO-PARTICLE INTEGRATING-BASED COLORIMETRIC SENSING:**

Colorimetric detection constitutes perhaps the least difficult and profitable nanosensing techniques on available. A traditional instance was creating through colorimetric evaluation for putative mapk inhibitor exploits on microplates for parallel screening utilizing the commercially accessible biotin-avidin system paired to AuNPs. Dairy goods-stabilized Au NPs were previously exploited to detect cholera corrode promptly. A red to purple hue change is the result of NPAggregation, which is triggered by the cholera corrode adhering to a dairy goods derivative. These techniques demonstrate that it is feasible to pinpoint relevant molecules and desired biological components without the need for sophisticated instruments by utilizing the plasmonic implementing inherent in aggregated NP systems.This technique is currently utilized for tracking cholesterol levels, pH changes, and DNA hybridization combining molecularly imprinted polymers, responsive polymer brushes, and surface-immobilized single-stranded DNA.

**18) UTILIZING OF RAYLEIGH SCATTERING FOR IMAGING AND SENSING:**

Target DNA was identified at picomolar accumulations adopting this technique, that additionally rendered it practicable for researchers to identify single-nucleotide polymorphisms (SNPs) without demanding temperature control. Spot tests based on light scattering in conjunction with 50-nm Au particles allowed for the recognization of considerably smaller volumes of target DNA. Plasmonic nanoparticles conjugated with antibodies encoding a protein overexpressed by ailments cells can be employed to detect cancer cells. Epidermal growth factor receptors (EGFRs) are transmembrane glycoproteins which have been overexpressed in an assortment of malignancies, including malignancies of the throat, salivary glands, bowels, breast area, and airway. Anti-HER2 (Human epidermal growth factor 2) and anti-EGFR antibodies are typically used to target EGFRs. Epidermal growth factor receptors (EGFRs) are transmembrane glycoproteins that are overexpressed in an assortment of malignancies, including cervical, bladder, breast, lung, and oral cancers. Anti-HER2 (Human epidermal growth factor 2) and anti-EGFR antibodies are typically utilised to target EGFRs individual tissues or cells. Have been subjected to antibody-conjugated plasmonic NPs, and the tagged cells—such as dark field microscopy or two-photon luminescence—are inspected using an adequate optical imaging technique. Different kinds of cancer cells have been imaged using both spherical AuNPs and nanorods connected with antibodies.

**19) LABEL-FREE OPTICAL AUTHENTICATION UTILISING REFRACTIVE INDEX ALTERATIONS:**

Recently, surface-immobilized spherical NPs have been utilized for recognizing phosphopeptides on titani-coated Au NPs at nanomolar levels in complex samples, besides to detect antibody binding to human serum albumin (HAS).[22]

**20) DETECTION OF ALZHEIMERS DISEASE:**

Alzheimer's disease (AD) patients necessitate tailored her interaction treatment plans and an early diagnosis, that relies on the multiplexed detection of AD core biomarkers. Our SERS biosensing equipment utilizes polyA aptamer-AuNPs (PAapt-AuNPs) conjugates configured with a Raman dye to in tandem detect Tau protein and Aβ(1-42) oligomers. The technique is based on a certain plasmonic integrating effect which arises from protein-aptamer binding-mediated AuNP aggregation, letting us to "turn on"SERS detection of protein biomarkers. Protein biomarkers can be swiftly recognized considering to the experiment's 15-minute completion time. The simultaneous detection of Tau protein and Aβ (1-42) oligomers by the use of Raman dye-coded nanoconjugates allows for diagnosing and prognosis of Alzheimer's disease.[23]

**21) DETECTION OF PCOS:**

Polycystic ovarian syndrome (PCOS) is a multifaceted, diverse condition that affects a large number of women of reproductive age. This shows how surface-enhanced Raman scattering (SERS) technology can distinguish between PCOS and non-PCOS patients. We found that using SERS in conjunction with PLS (partial least squares) and PCA (Principle component analysis) enabled us to detect PCOS in patient samples. Although the significance of chemerin in the etiology of PCOS patients is unknown, this allows us to evaluate their chemerin levels using the PLS regression technique. Chemerin accumulations were tested in PBS[phosphate buffered saline] and FF [Folicular fluid]samples. Raman peaks at 724, 1001, 1028, and 1224 cm−1 correlate strongly with chemerin levels in PCOS and non-PCOS samples.[24]

**22) QUANTITATIVE ANALYSIS OF GLUCOSE:**

A surface-enhanced Raman scattering (SERS) sensor based on etching silver nanoparticles (Ag NPs) was developed to detect glucose with great sensitivity and ease of use. Ag NPs marked with Raman tags of 4-mercaptopyridine (4-mpy) were formed on the glass slide by layer-by-layer self-assembly to construct a SERS chip. Exposing this SERS chip to varying quantities of glucose and glucose oxidase-mixed solutions caused H2O2 to etch the Ag NPs, resulting in a decrease in the 4-mpy SERS signal. By tracing the SERS intensity of 4 - mpy, we can detect glucose accumulations as low as 10 μM. This glucose sensor has the prospect of clinical blood detection in the decades to come.[25]

**23) DETECTION OF PARKINSONS DISEASE:**

Parkinson's disease (PD) is an acute and progressive neurological condition, and early diagnosis is critical for improving patient survival. $\alpha$-Synuclein ($\alpha$-syn) is a possible biomarker for the early diagnosis of Parkinson's disease. A biosensing platform is needed to properly detect this protein in human body fluids. Our SPR biosensor uses label-free iron oxide nanoparticles (Fe3O4 NPs) and coupled antibodies to detect $\alpha$-syn in serum samples with great sensitivity and selectivity. The sensitivity of the SPR platform is greatly improved by directly depositing Fe3O4 NPs at a high density on the Au surface, which increases the decay length of the evanescent field on the Au film. Using rabbit-type monoclonal antibodies ($\alpha$-syn-RmAb) mounted on Au films improves the SPR platform's affinity-selectivity binding performance compared to mouse-type monoclonal antibodies, a common bioreceptor for trapping $\alpha$-syn molecules. The current platform detects 5.6 fg/mL, which is 20,000 times lower than commercial ELISA. The enhanced sensor chip accessible regenerated, allowing for consistent $\alpha$-syn measurements.The SPR sensor was utilized for direct measurement of $\alpha$-syn in serum samples. Using paired $\alpha$-syn-RmAb, the SPR sensor accurately detects $\alpha$-syn in diluted serum samples with a recovery rate of 94.5% to 104.3%. This study shows a sensitive and selective method for detecting $\alpha$-syn in human biofluids, potentially leading to early diagnosis of Parkinson's disease.[26]

**24) BIODIAGNOSTICS:**

The utilisation of nanomaterials for identify biomarkers for illness are leading to ultrasensitive assays. These assays identify multiple distinctive biomarkers for various disorders. The subsequent yearsof plasmon-enabled biodiagnostics depends on focusing on ideal qualities of evaluates with clinical survivability and clinical diagnostics using nanoparticles, which have showed feasibility of Clinical transfer when engineered into nano-enabled systems. Diagnostic processes are essential for the reliable remedy for all illnesses, hence focusing on diagnostic tools is critical. The complete eradication of disease relies upon breakthroughs in prevention and treatment, yet misdiagnosis of life-threatening conditions may incur vital time spent pursuing care. An fruitful bio-interface can be developed by nanoparticles with multivalent surface structures bonded to distinct functional categories for particular liaisons with bio-relevant targets for instance DNA, proteins, and cells. We may deliver the necessary capabilities for utilization in clinical diagnostics owing to the comparatively straightforward functionalization techniques of nanomaterials. Particles can be coated with polymers that provide steric hindrance to aggregation, for instance polyethylene glycol and dendrimers, or capped with charged molecules that provide electrostatic repulsion (for example, saturated with carboxylic acid groups that are negatively charged at physiological pH). These capping agents play a vital part in the formation and colloidal stability of nanoparticles. Significant lateral inter-particle dispersion forces caused by interaction may be exerted with gold nanorods (GNRs). Various techniques have been utilized, for instance, physisorbed charged polymers and covalently connected quaternary amines; however, a novel strategy is the use of thiol-terminated polyethylene glycol to generate a steric layer that surrounds the particles. Tight packing of the layer is essential in order to provide attractive steric stabilization in aqueous solvents that are rich in electrolytes. This guarantees that the

steric layer will be sufficiently thick to prevent nanorod aggregation even in cases when polymer solubility is decreased.[27]

## 25) PLASMONICS FOR HEALTH:

The biomedical area has considerably benefited from extensive study on the characteristics of plasmonic nanoparticles, resulting in significant breakthroughs, particularly in diagnosis and therapy. The present trends extend beyond the utilization of plasmonic structures as pharmacological regulators and markers and towards theranostics, which is the combining of several capabilities inside a single nanostructure. The ability to use a single compound for deux separate functions does offer bringing up extra possibilities for the progress of medicine. Plasmonic nanoparticles been striving as contrast agents in optical imaging due to their effective light scattering capabilities. Targeted gold nanoparticles can produce highly juxtaposed representations of cancerous cells by applying of several optical methods, notably dark-field microscopy, reflectance confocal microscopy, photoacoustic imaging, the initial and second one-photon fluorescence imaging, and surface-enhanced Raman scattering (SERS). In the medical field, they have been utilized to pinpoint various types of disease biomolecules including as proteins and enzymes. They furthermore been accustomed to identify DNA and pharmaceuticals in a very quick and sensitive manner. Plasmonic nanoparticles accumulate passively at tumour locations via an action titled increased permeability and retention, allowing them to render accessible a medicine after the aim has been reached or to photothermally destroy cancereous cells.[28]

## REFERENCES

1. ODOM TW, SCHATZ GC. INTRODUCTION TO PLASMONICS. CHEMICAL REVIEWS [INTERNET]. 2011 MAY 11;111(6):3667–8. AVAILABLE FROM: HTTPS://DOI.O/1RG0.1021/CR2001349

2. Barbillon G. Plasmonics and its Applications. Materials [Internet]. 2019 May 8;12(9):1502. Available from: https://doi.org/10.3390/ma12091502

3. Stewart ME, Anderton CR, Thompson LJ, Maria J, Gray SK, Rogers JA, et al. Nanostructured plasmonic sensors. Chemical Reviews [Internet]. 2008 Jan 30;108(2):494–521. Available from: https://doi.org/10.1021/cr068126n

4. Murray WA, Barnes W. Plasmonic materials. Advanced Materials [Internet]. 2007 Oct 26;19(22):3771–82. Available from: https://doi.org/10.1002/adma.200700678

5. Lu X, Rycenga M, Skrabalak SE, Wiley B, Xia Y. Chemical synthesis of novel plasmonic nanoparticles. Annual review of physical chemistry. 2009 May 5;60:167-92.

6. Ahmadivand A, Gerislioglu B, Ahuja R, Mishra YK. Terahertz plasmonics: The rise of toroidal metadevices towards immunobiosensings. Materials Today [Internet]. 2020 Jan 1;32:108–30. Available from: https://doi.org/10.1016/j.mattod.2019.08.002

7. Sohrabi F, Saeidifard S, Ghasemi M, Asadishad T, Hamidi SM, Hosseini SM. Role of plasmonics in detection of deadliest viruses: a review. The European Physical Journal Plus [Internet]. 2021 Jun 20;136(6). Available from: https://doi.org/10.1140/epjp/s13360-021-01657-9

8. Shrivastav AM, Cvelbar U, Abdulhalim I. A comprehensive review on plasmonic-based biosensors used in viral diagnostics. Communications biology. 2021 Jan 15;4(1):70.

9. Zeni L, Perri C, Cennamo N, Arcadio F, D'Agostino G, Salmona M, et al. A portable optical-fibre-based surface plasmon resonance biosensor for the detection of therapeutic antibodies in human serum. Scientific Reports [Internet]. 2020 Jul 7;10(1). Available from: https://doi.org/10.1038/s41598-020-68050-x

10: Shahbazi N, Zare-Dorabei R, Naghib SM. Multifunctional nanoparticles as optical biosensing probe for breast cancer detection: A review. Materials Science and Engineering: C [Internet]. 2021 Aug 1;127:112249. Available from: https://doi.org/10.1016/j.msec.2021.112249

11. Huang X, El-Sayed MA. Plasmonic photo-thermal therapy (PPTT). Alexandria Journal of Medicine [Internet]. 2011 Mar 1;47(1):1–9. Available from: https://doi.org/10.1016/j.ajme.2011.01.001

12. Keshavarz A, Zangenehzadeh S, Hatef A. Optimization of surface plasmon resonance-based biosensors for monitoring hemoglobin levels in human blood. Applied Nanoscience [Internet]. 2020 Jan 16;10(5):1465–74. Available from: https://doi.org/10.1007/s13204-020-01252-x

13. Tan SJ, Campolongo MJ, Luo D, Cheng W. Building plasmonic nanostructures with DNA. Nature Nanotechnology [Internet]. 2011 Apr 17;6(5):268–76. Available from: https://doi.org/10.1038/nnano.2011.49

14. Olaru A, Bala C, Jaffrézic-Renault N, Aboul-Enein HY. Surface plasmon resonance (SPR) biosensors in pharmaceutical analysis. Critical Reviews in Analytical Chemistry [Internet]. 2015 Jan 6;45(2):97–105. Available from: https://doi.org/10.1080/10408347.2014.881250

15: Kumbhat S, Sharma K, Gehlot R, Solanki A, Joshi V. Surface plasmon resonance based immunosensor for serological diagnosis of dengue virus infection. Journal of Pharmaceutical and Biomedical Analysis [Internet]. 2010 Jun 1;52(2):255–9. Available from: https://doi.org/10.1016/j.jpba.2010.01.001

16: Altıntaş Z, Uludağ Y, Gürbüz Y, Tothill IE. Surface plasmon resonance based immunosensor for the detection of the cancer biomarker carcinoembryonic antigen. Talanta [Internet]. 2011 Oct 1;86:377–83. Available from: https://doi.org/10.1016/j.talanta.2011.09.031

17. Moosavi R, Zibaseresht R. Efficient cyanide sensing using plasmonic Ag/Fe 3 O 4 nanoparticles. RSC advances. 2023;13(47):33120-8.

18. Stewart ME, Anderton CR, Thompson LB, Maria J, Gray SK, Rogers JA, Nuzzo RG. Nanostructured plasmonic sensors. Chemical reviews. 2008 Feb 13;108(2):494-521.

19. Lee JY, Mohammadi M, Wang Y. Detecting and differentiating neurotransmitters using ultraviolet plasmonic engineered native fluorescence. RSC advances. 2023;13(46):32582-8.

20. Humbert C, Noblet T, Dalstein L, Busson B, Barbillon G. Sum-frequency generation spectroscopy of plasmonic nanomaterials: A review. Materials. 2019 Mar 12;12(5):836

21. Beeram R, Vepa KR, Soma VR. Recent trends in SERS-based plasmonic sensors for disease diagnostics, biomolecules detection, and machine learning techniques. Biosensors. 2023 Feb 27;13(3):328.

22. Stewart ME, Anderton CR, Thompson LB, Maria J, Gray SK, Rogers JA, Nuzzo RG. Nanostructured plasmonic sensors. Chemical reviews. 2008 Feb 13;108(2):494-521.

23. Zhang X, Liu S, Song X, Wang H, Wang J, Wang Y, Huang J, Yu J. Robust and Universal SERS Sensing Platform for Multiplexed Detection of Alzheimer's Disease Core Biomarkers Using PAapt-AuNPs Conjugates. ACS Sens. 2019 Aug 23;4(8):2140-2149. doi: 10.1021/acssensors.9b00974. Epub 2019 Aug 8. PMID: 31353891.

24. Ali Momenpour, Patrícia D. A. Lima, Yi-An Chen, Chii-Ruey Tzeng, Benjamin K. Tsang, and Hanan Anis, "Surface-enhanced Raman scattering for the detection of polycystic ovary syndrome," Biomed. Opt. Express 9, 801-817 (2018)

25. Qi, G.; Jia, K.; Fu, C.; Xu, S.; Xu, W. A Highly Sensitive SERS Sensor for Quantitative Analysis of Glucose Based on the Chemical Etching of Silver Nanoparticles. *J. Opt.* **2015**, *17*, 114020. [**Google Scholar**] [**CrossRef**]

26. Mandala SH, Liu TJ, Chen CM, Liu KK, Januar M, Chang YF, Lai CS, Chang KH, Liu KC. Enhanced plasmonic biosensor utilizing paired antibody and label-free Fe3O4 nanoparticles for highly sensitive and selective detection of Parkinson's α-Synuclein in serum. Biosensors. 2021 Oct 18;11(10):402.

27. Howes PD, Rana S, Stevens MM. Plasmonic nanomaterials for biodiagnostics. Chemical Society Reviews. 2014;43(11):3835-53

28. de Aberasturi DJ, Serrano-Montes AB, Liz-Marzán LM. Modern applications of plasmonic nanoparticles: from energy to health. Advanced Optical Materials. 2015 May;3(5):602-17