SURFACE-ENHANCED RAMAN SCATTERING (SERS) GENE PROBES FOR MEDICAL DIAGNOSTICS
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We describe the development of nanotechnology for surface-enhanced Raman scattering (SERS) applications. We illustrate the development of a variety of sensors and a multifunctional DNA chip for SERS method and instrumentation. The research area involves the development of metallic nanoparticles that produce a high-field effect for ultrasensitive biochemical analysis. The intensity of the normally weak Raman scattering process is increased by factors as large as 10^14 by compound adsorption onto a SERS substrate, allowing for trace-level detection. The SERS nanoparticle technique has been incorporated in several clinical models for the detection and classification of biological analytes. These nanoscale, multifunctional sensors can be used to detect DNA targets via hybridization to DNA sequences complementary to these probes. The probes do not require the use of radioactive labels and have great potential for use in simultaneous multi-analyte labeling for biomedical imaging.

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Introduction

- The development of practical and sensitive devices for screening multiple genes related to medical diseases and infectious pathogens is critical for early diagnosis and improved treatments of many illnesses.
- A major factor in medical diagnosis is rapid, selective and sensitive detection of biochemical substances, biological species or living systems at ultra-trace levels in biological samples, which often requires detection methods that are capable of identifying and differentiating a large number of biochemical components in complex biological samples simultaneously.
- Raman spectroscopy is a technique that has multi-component analysis potential and requires little sample preparation, which allows for on-line and in-field analysis.
- Raman scattering efficiency can be enhanced by factors >10^4 when a compound is adsorbed on or near special metal surfaces. The enhancement provided by surface-enhanced Raman scattering helps to bridge the sensitivity gap between the fluorescence and Raman techniques; therefore, the SERS gene probes can be a unique combination of performance capabilities and analytical features of merit.

Principle of Raman spectroscopy

Raman scattering intensity

\[ I = \frac{p \cdot \sigma \cdot c}{h} \]

- Quantum efficiency of the molecule
- Incident electric field magnitude

Mechanisms of Plasmonics and Surface-Enhanced Raman Scattering (SERS)

Plasmonics refers to the research area of enhanced electromagnetic properties of metallic nanostructures. The term plasmonics is derived from "plasmons", which are the quanta associated with longitudinal waves propagating in matter through the collective motion of large numbers of conduction electrons. Incident light irradiating these surfaces excites conduction electrons in the metal, and induces excitation of surface plasmons leading to enormous electromagnetic enhancement of special signature (such as surface-enhanced Raman scattering (SERS) and surface-enhanced fluorescence (SEF)) for ultrasensitive biological detection and imaging.

Electromagnetic Enhancement (EFactor)

- Incident radiation (IR) induces oscillation of conduction electrons in the metal surface, generating a secondary field.
- When incident radiation at the plasma frequency, a resonant response of conduction electrons (surface plasmon) generates an enhanced secondary field.

Molecular Enhancement (MFactor)

- Charge transfer between the metal and adsorbate can enhance the transition probability.

Examples of SERS-active dyes and nanostructures

- SERS-active dyes and nanostructures
- A common feature of SERS substrates is atomically rough surfaces
- Spectral dyes with enhancement of different photonics examinations

Advantages of Raman (SERS) techniques to bioscience

- Noninvasive
- High sample selectivity. Very narrow bands (~1 nm) may enable detection of multiple probes simultaneously
- Label-free

Surface-enhanced Raman scattering (SERS) is a potential solution

- SERS provides a means to enhance factor of about 10^14 making it competitive with fluorescence for certain trace analysis applications. SERS results are not affected by the adsorption of chemicals on a sub-micron textured surface.
- Resonance can also enable up to 10^6 factor enhancement

Motivation

- The development of plasmonics and SERS methods and instrument for use in clinical medical diagnosis and imaging is described.
- The fundamental research on surface enhanced Raman scattering (SERS) and surface-enhanced fluorescence (SEF) for ultrasensitive biological detection and imaging.

Conclusions

- The development of plasmonics and SERS methods and instrument for use in clinical medical diagnosis and imaging is described.
- The ability to enhance the Raman scattering signal by factors as high as 10^14 by the adsorption of metallic nanoparticles onto biological samples, allowing for trace-level detection.
- Advanced plasmonic systems designed for point-source spectral measurements and for multi-spectral imaging (MSI) are described. The MSI concept allows reporting the entire SERS spectrum for every pixel on the two-dimensional hybridization platform in the field of view with the use of a real-scanning solid-state device, such as AOTF.
- Investigation of DNA/protein microarrays in cells is currently under way.

References