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Plasmonic Nanoparticles with Ultrasmall Nanogap

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ABSTRACT

Designing, synthesizing and controlling plasmonic nanostructures such as Au and Ag nanoparticles (AuNPs and AgNPs) with high precision and high yield are of paramount importance in optics, nanoscience, materials science and nanobiotechnology. It is particularly important to generate and control ~1-nm plasmonic gap because plasmonic gaps of ~1 nm or less can generate exponentially stronger plasmonic coupling signals than >1-nm plasmonic gap. Among many examples of the use of plasmonic nanogap, surface-enhanced Raman scattering(SERS)-based signal amplification and bio-detection methods using SERS-active plasmonic nanoparticles (NPs) have been drawing significant interest, and it has been known that SERS effect is very intense when Raman dyes are located within <1-nm inter-particle junction. Here, I will describe DNA-based synthetic strategies to build up new types of plasmonic nanogap Au/Ag structures with high structural controllability. The use of these plasmonic nanostructures including anisotropic nanostructures as excellent optical signal enhancement platforms in detecting biomolecules sensitively, quantitatively and specifically will be presented especially for ~1-nm plasmonic gap probes. Other biosensing applications of these plasmonic probes including plasmonic nanoprobe-tethered supported lipid bilayer system will be also shown and discussed in this presentation.

1. INTRODUCTION

Metallic nanoparticles are of paramount importance because of their useful properties such plasmonic optical property and catalytic activities. It is, however, very challenging to design and synthesize metallic nanostructures with the desired structure and property, and achieving this synthetic need is critical for the use of metallic nanostructures for plasmonic applications such surface-enhanced Raman scattering (SERS), dark-field light scattering, nanoantenna, metamaterials and metal-enhanced fluorescence (MEF). In our lab, we are designing and developing various types of plasmoic nanostructures that meet the challenges described above. Main components that have been adopted are gold and silver nanoparticles, DNA and lipid bilayer.

2. PLASMONIC NANOPROBES WITH NANOGAP AND ENHANCED OPTICAL PROPERTIES.

A basic scheme here is to bring two plasmonic particles via the specific recognition of target molecules such as proteins and DNA, followed by plasmonic shell formation to engineer the gap between two nanoparticles to enhance the detection signal (Fig. 1). Using this rather simple scheme, one can optimize the detection signal intensity and develop assays that can sensitively and quantitatively detect targets of interest. It is important to notice that the controllable generation of ~1-nm gap between plasmonic nanostructures is the key to the generation of strong and controllable plasmonic signals from the plasmonically coupled nanostructures.

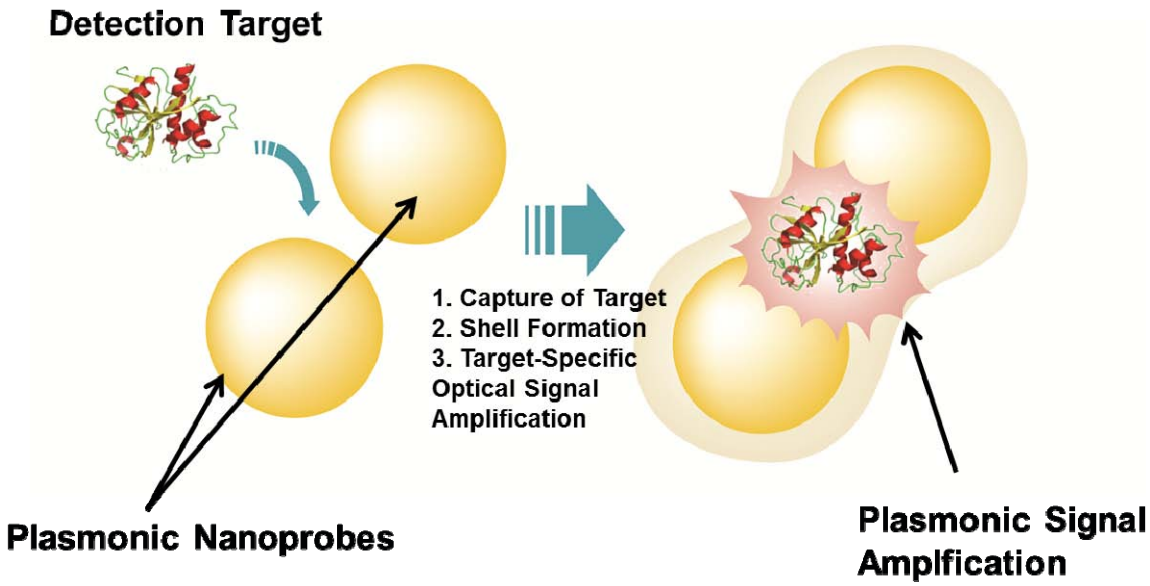

Fig. 1. Schematic illustration of dimeric plasmonic coupling-based bioprobes.

3. TETHERING PLASMONIC NANOPROBES ON LIPID BILAYER AND THEIR COUPLINGS

On a fluidic 2D supported lipid bilayer platform, we modified plasmonic nanoparticles in a dynamic fashion. By tethering and tracking plasmonic nanoparticles on a lipid bilayer surface with dark-field microscopy, one can analyze their movements and interactions in situ, and this offers a tool for real-time analysis of interacting molecules and particles on a two-dimensionally confined dynamic substrate. In principle, by differentiating the plasmonic coupling-based dark-field color change and dwelling time of interacting particles, interacting particles pairs can be imaged and analyzed in quantitative and reliable manner (Fig. 2).

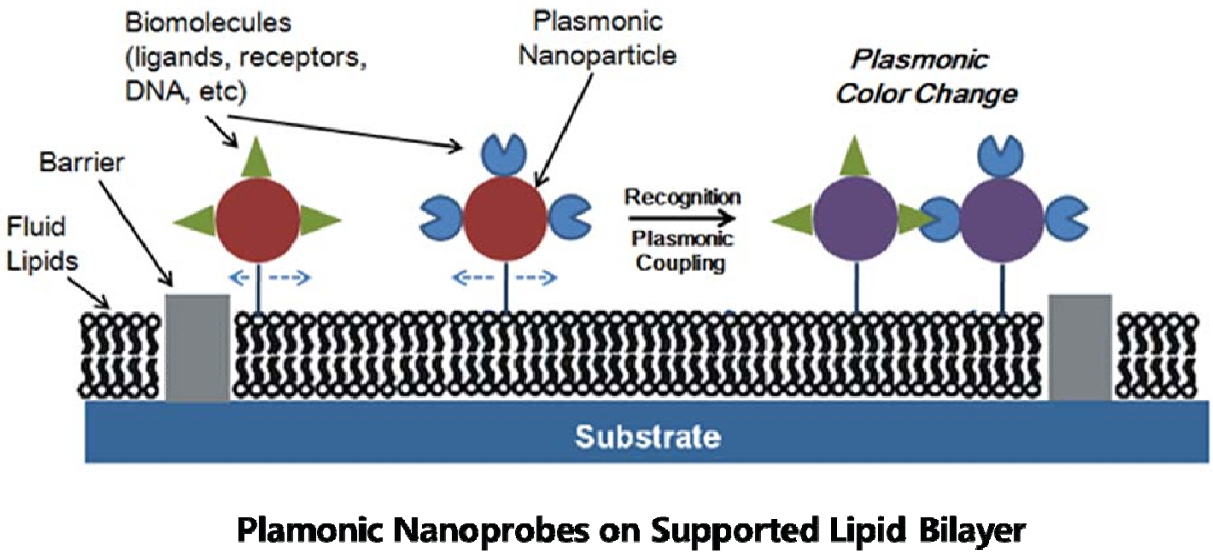

Fig. 2. Metallic Nanoparticle-Tethered Lipid Bilayer System and Coupling between Nanoparticles.

3. CONCLUSIONS

By carefully designing and synthesizing DNA-modified plasmonic nanoparticles with various structural features and quantitative ligand modification strategies, one can reliably synthesize plasmonic nanostructures that can be controllably and quantitatively assembled and disassembled via the specific recognition of molecules of interest. These functional probes can be assembled in solution, glass surface and fluidic lipid bilayer substrate. These dynamic and controllable assembly of plasmonic nanoprobes with ultrasmall nanogap can offer new and improved platforms for the detection of biomolecules.

4. REFERENCES

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