Active Plasmonic Nanostructures in Biosensing and Imaging

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Noble Metal Nanoparticles



The alternating surface charges effectively form an oscillating dipole, which radiates electromagnetic waves.







Single Particle Rayleigh Spectroscopy







3 µm

Sonnichsen et al., Phys. Rev. Lett, 88, 077402 (2002).







Tuning Plasmons



Plasmon Coupling

(Nanoparticle Assemblies enable additional Functionalities)



Talley et al. Nano Lett, 5, 1569 (2005).







Distance Dependent Plasmon Coupling









Problem for rational assembly strategies of active nanostructures: (In)Stability of Colloids









RNA Plasmon Rulers









Plasmon Ruler Calibration



Reinhard et al. Nano Letters, 5, 2246 (2005).







Highly parallel in vitro single molecule assay for RNA

Restriction Nucleases such as the Dicer Enzyme are important enzymes involved in transcription regulation.

They create the correct substrates for the siRNA and miRNA processing machinery.

Other potential applications: Mechanochemistry of viral Nucleoprotein-RNA complexes



Zhou et al, Science 311, 195 (2006)







Single RNA Cleavage Assay











1000 nm







Spermidine modulated RNase A Activity











Spermidine modulated RNase A Activity









(One) Secondary Structure









Measuring Distance and Orientation Changes



$$P = \frac{I_1 - I_2}{I_1 + I_2}$$

H. Wang & B. M Reinhard, J. Phys. Chem. C 113, 11219 (2009)







Polarization Resolved Compaction Trajectories









Simulation of Polarization Anisotropy in the Dipolar Coupling Limit









Distance and Refractive Index Dependencies









Silver Plasmon Rulers

























Plasmon Coupling between 2-Dimensionally Confined Probes



Rong et al, Nano Letters, 8, 3386 (2008)







Receptor Clustering









Plasmon Coupling Microscopy (PCM)









Calibration of PCM with 530/580 nm channels









Resolving Sub-Diffraction Limit Contacts Using PCM









Future Directions of PCM

The performed proof of principle experiments show that PCM is capable of resolving sub-diffraction limit distances between individual particles diffusing on a cellular membrane.

PCM could be a useful tool to detect and monitor dynamic contacts between individual gold nanoparticle labeled membrane components.

One important challenge that lies ahead is the specific labelling without perturbation of the biological functionality.







Engineered SERS Substrates for Rapid Pathogen Detection BUPC Collaboration with DalNegro/Ziegler



Cell wall structure of Gram(-) bacteria. The bacteria have a thin peptidoglycan layer and an outer membrane that contains phospholipids and proteins.







Active Market to trace for Survival and Inveging

for Engineered SERS Substrates: **Nanoparticle Dimers with Junction** Plasmons





Talley et al. Nano Lett, 5, 1569 (2005).





BU College of Arts & Sciences

(2003)



Nanoparticle Cluster Arrays: Improved Building Blocks Through Combined Top-**Down/Bottom-Up Fabrication**



Ebeam lithography is used to define binding sites for the template assisted self-assembly of nanoparticles.

Yan et al, ACS Nano, 3, 1190 (2009).







Control over Average Cluster Size









Control over Intercluster Separation









Calibration of SERS Performance with para-Mercaptoaniline (pma)









NCAs vs. Random Colloidal Substrates and "Smooth" Gold Nanoparticle Arrays









SERS Characterization and **Identification of Bacterial Pathogens**









Advantages of Engineered SERS **Substrates for Bacterial Diagnostics**

- High substrate to substrate and on chip reproducibility
- Rational fabrication approach allows optimization of substrates for specific samples (bacteria versus spores for instance)
- Fabricated SERS chips can be interfaced into microfluidic devices for intergrated solutions







SERS Analysis of Bacteria





Analysis of Spectra through PCA / DFA



Conclusions

- Plasmon rulers are maturing into a robust highly parallel assay for distance and orientation measurements on the single molecule level
- Plasmon Coupling Microscopy (PCM) capable of resolving sub-diffraction resolution limit contacts with high temporal resolution.
- Nanoparticle Cluster Arrays engineerable SERS platform with high reproducibility that enable to create hot-spots at will at defined locations.







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