Plasmonics of Nano-Gaps

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Introduction: The local electric-field enhancement in a system of dielectric nanoparticle placed very near to a metallic substrate is studied [1, 2]. Under appropriate excitation conditions, the gap between the particle and the substrate becomes a 'hot-spot', i.e. a region of intense electromagnetic field.

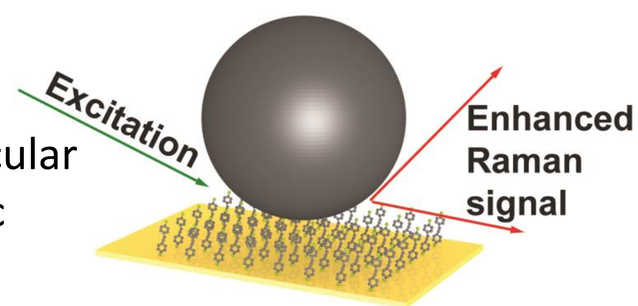

Figure 1. Dielectric nanoparticle above molecular monolayer on metallic substrate.

Computational Methods: A 3D model, using COMSOL Multiphysics® v4.3 RF Module, was constructed to enable parametric studies. The simulations were performed in two steps: (1) compute the electric field for the substrate only when illuminated by a plane-wave excitation at the upper boundary; (2) solve for the electric field due to the presence of the nanoparticle on the substrate, using the output from the first step. Perfectly-matched layers (PMLs) were used to absorb the scattered radiation in all directions. In order to reduce the computational time, symmetry planes were used and only one fourth of the model was solved for.

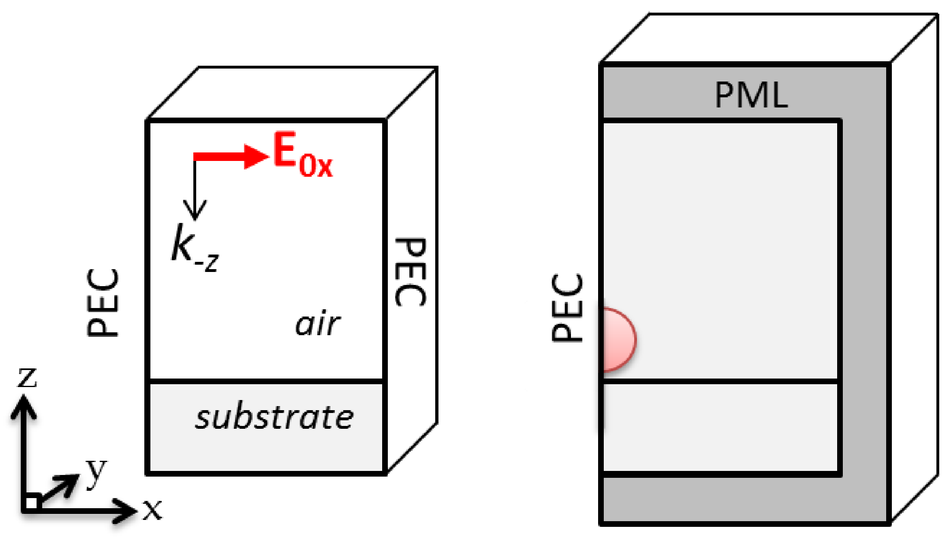

Figure 2. Schematic illustration of two computational steps.

Results: Simulations showed that higher values of the real and imaginary refractive index of the nanoparticle leads to stronger field enhancement in the gap.

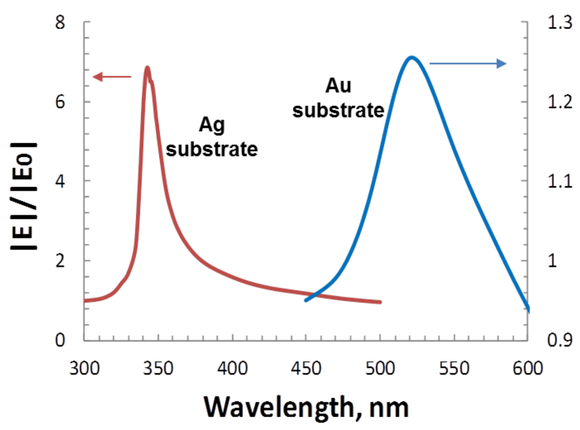

Figure 3. The maximum electric field in the gap for silver and gold substrates.

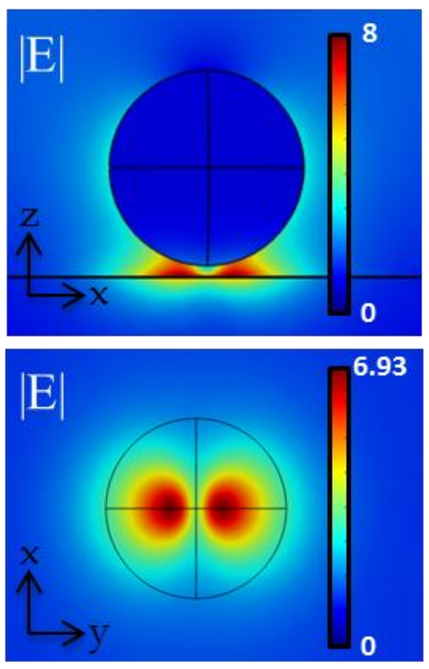

Figure 4. Spatial field distributions for a dielectric nanoparticle placed above a silver substrate at 343 nm.

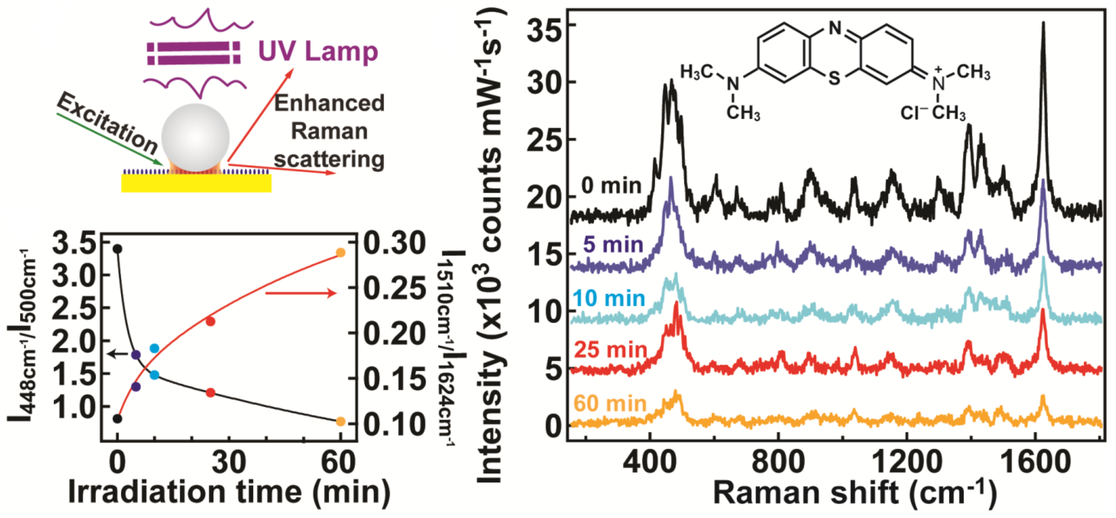

Figure 5. Photocatalysis and simultaneous monitoring of methylene blue spectra after different exposures to UV irradiation [2].

Conclusions: A dielectric nanoparticle acts as a source of plasmon excitation for an underlying metallic substrate. Dielectric materials with higher optical constants will result in higher near-field enhancements. Metal-oxide nanoparticle above a metallic substrate can generate strong surface-enhanced Raman scattering signals, and can be used for various applications that are not possible with all-metallic systems.

References:

1. T. Hutter, F.M. Huang, S.R. Elliott and S. Mahajan, '**Near-field plasmonics of an individual dielectric nanoparticle above a metallic substrate**' The Journal of Physical Chemistry, C 117(15) 7784-7790, 2013.
2. L. Li, T. Hutter, A.S. Finnemore, F.M. Huang, J.J. Baumberg, S.R. Elliott, U. Steiner and S. Mahajan, '**Metal oxide nanoparticle mediated enhanced Raman scattering and its use in direct monitoring of interfacial chemical reactions**' Nano Letters 12(8) 4242-4246, 2012.

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