PLASMONIC INTERACTION AT THE GAP IN A METALLIC NANO TIP AND A THIN FILM SYSTEM

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Tip-enhanced Raman spectroscopy (TERS), which is based on a plasmonic scanning probe tip, is an essential technique that allows nano-scale analysis of molecules. In particular, gap-mode TERS configuration allows access to ultra-high sensitive characterization and spatial resolution down to the single molecular level. To further improve the spatial resolution, control and understanding of the plasmonic property of the tip is indispensable. Here, I investigate the plasmonic interaction in the gap of a metallic nano tip and a thin film system using finite-difference time-domain (FDTD) method. The optical properties of the excited localized surface plasmon at the metallic gap are elucidated by changing the thickness of the thin film. The localized surface plasmon at the tip is hybridized with a continuum of surface plasmon on the film, which exhibits the tunable resonance energy of the localized surface plasmon at the gap according to the film thickness. Field enhancement confined at the gap under the plasmon resonance condition is discussed with respect to sensitivity and resolution.

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Raman Nanoscopy

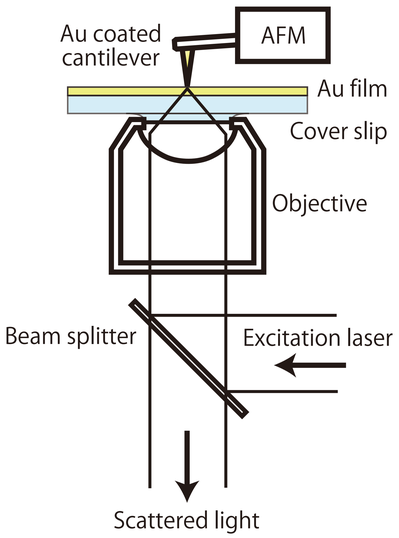
Provides us with a significant color-image of molecules at the nano-scale resolution[1]. Tip-enhanced Raman spectroscopy (TERS), — based on a plasmonic scanning probe tip —, allows nano-scale analysis of molecules.

[1] *T. Yano et al., Nature Photon., **3**, 473 (2009)*

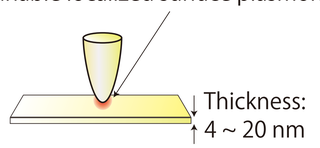
Purpose

To improve spatial resolution and sensitivity down to single molecular level by introducing a metallic thin film in order to create a nano-gap.

Gap-mode tip-enhanced Raman spectrosocpy (TERS)

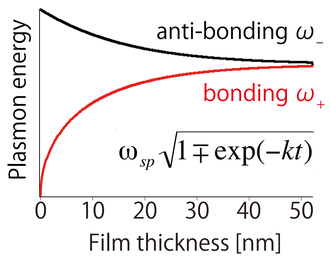


Tunable localized surface plasmon[2]



[2] *F. Le et al., Nano Lett., **5**, 2009 (2005)*

Plasmonic property of a thin film



Finite-difference time-domain (FDTD) analysis

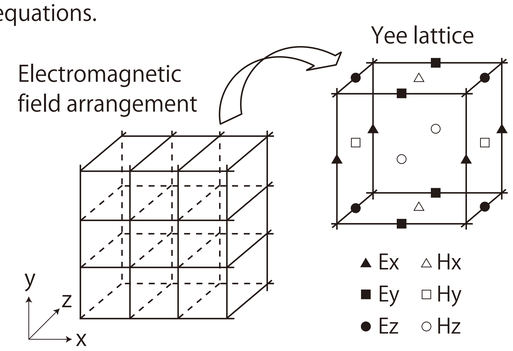
Electric and magnetic field vector components are calculated according to the descritized Maxwell equations.

Maxwell equations

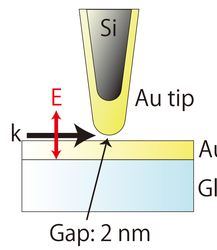
$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}$$

$$\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} - \sigma \vec{E}$$

Electromagnetic field arrangement

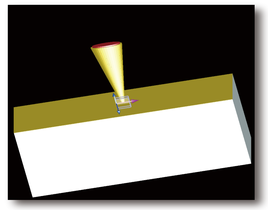


Configuration for the FDTD analysis



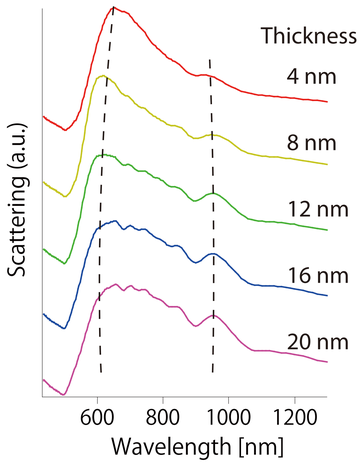
Mesh: 1x1x1 nm^3
Apex size: 30 nm
Apex angle: 20°

3D perspective

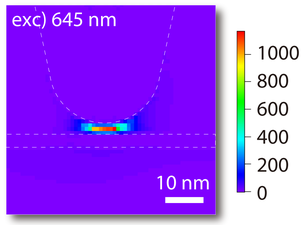


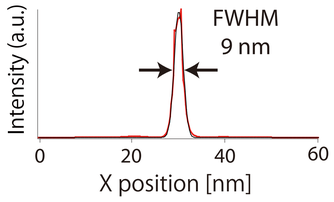
Calculated scattering spectra and field enhancement

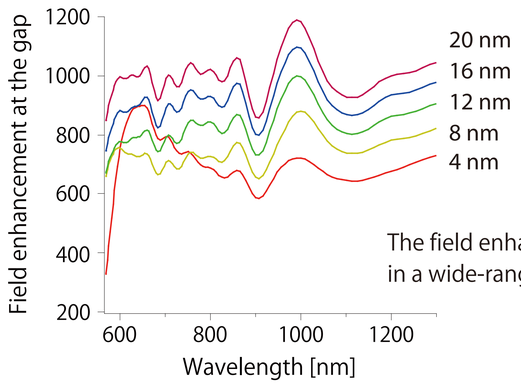
Peak positions are slightly changed according to the thickness.



Field distribution (film: 4 nm)





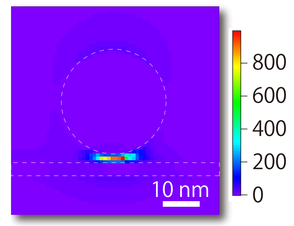


The field enhancement is observed in a wide-range wavelength.

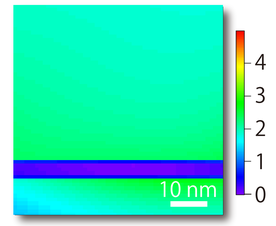
Comparison with nanoparticle-film system

Plasmon resonance energy in a nanoparticle-film system is tuned by a thickness of the film.

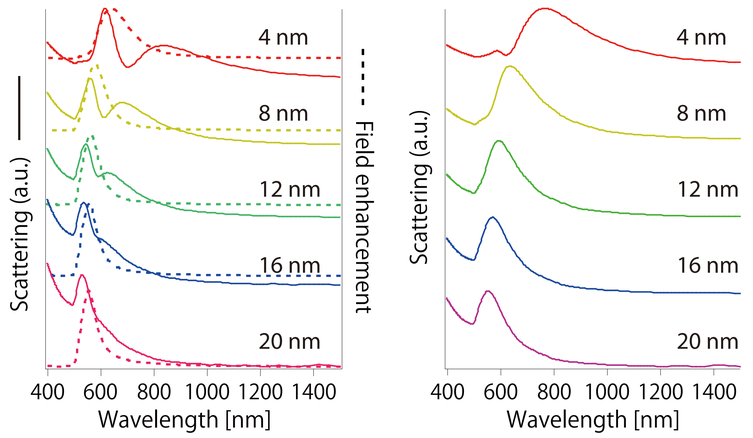
Nanoparticle-file system



A thin film (film: 4 nm)



Scattering specta and field enhancement



Tunable plasmon resonance in the nanoparticle-film system is observed, although surface plasmon on a film is excited where the surface plasmon is theoretically not coupled to the incident light.

Conclusion

- Plasmonic property at the tip-film gap is obtained by the FDTD analysis.
- The plasmonic property at the gap is tuned by the film thickness.
- The large field enhancement can be achieved in a wide-range wavelength.

Acknowledgement

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