Plasmonic heating of single gold nanoparticles at multi-interfaces

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Plasmonic nanoparticles have attracted a great deal of research interests because of strong local electric-field enhancement that is applicable to SERS and metal-enhanced fluorescence. As a detection method, these techniques have potential of sensing molecules of very low concentrations, even to the single molecule level by applying a microscope with laser illumination. In this instance, however, strong focusing of illuminating laser onto single gold or silver nanoparticles (NPs) may result in severe particle heating. [1]

Here we describe the fundamental aspects of single Au NP heating and heat transfer to the surroundings consisting of a substrate and a medium. Importantly, we could experimentally determine the particle temperatures dependent on illuminating laser intensity, exploiting temperature-induced plasmon band bleaching. [1] The particle temperatures thus determined were in good agreement with those obtained by numerically solving a 3D heat transfer equation. [2]

Figure 1 shows the particle temperature (T_p) *vs.* laser intensity (I) curves for a single Au NP supported on a glass substrate and exposed to air, glycerol and water. We observed linear relationships between T_p and I, the slope of which is dependent on the thermal conductivities (k's) of the media. This suggests that the heat transfer in these systems can be approximated by 1D heat transfer, despite the disparity of k's of the medium and the substrate. From the slopes of the T_p *vs.* I curves, we obtained the effective thermal conductivities of the systems consisting of three substrates and three media. The heat transfer of s Au NP was examined by numerical calculations solving the 3D heat transfer equation. Figure 2 (a) is the 2D temperature distribution in water/ glass and Fig. 2 (b) is that in water/sapphire. The heat transfer in water/sapphire is severely unisotropic; because of a strong cooling effect by sapphire, T_p can increase only slightly. This was consistent with the experiment. We also observed melting and evaporation of Au NPs at high intensities [3].

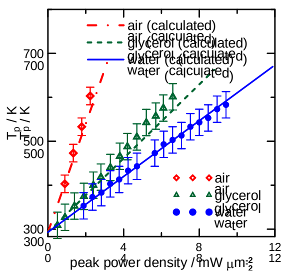

Fig. 1: *Laser peak power density vs. T_p relationship for a d=100 nm Au NP supported on a glass substrate that is exposed to air, glycerol, and water.*

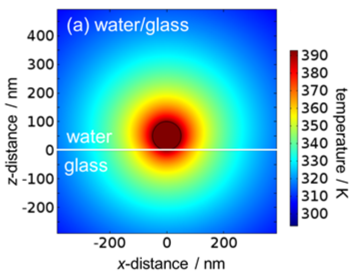

Fig. 2 (a): *Calculated 2D temperature distribution for a Au NP supported on a glass substrate and exposed to water.*

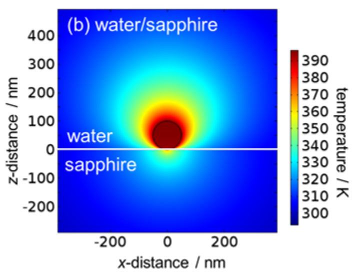

Fig. 2 (b): *Calculated 2D temperature distribution for a Au NP supported on a sapphire substrate and exposed to water.*

[1] K. Setoura et al., J. Phys. Chem. C, 116 (2012) 15458-15466.
[2] K. Setoura et al., ACS Nano, 7 (2013) 7874-7885.

[3] K. Setoura et al., Phys. Chem. Chem. Phys., 16 (2014) 26938-26945.