Single gold nanoparticle-heating-induced flow generation and trapping

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Optothermal trapping has gained increasing popularity in manipulation such as selecting, guiding, and positioning submicron objects because of a few mW laser power much lower than that required for optical trapping. The optothermal trapping uses thermal gradient induced thermal-gradient-induced phoretic motions, but the underlying physics of driving force has not been fully understood. In this study, we performed optothermal trapping of 500 nm-diameter colloidal silica via a continuous laser illumination of a single gold nanoparticle from the bottom in a closed chamber. Under illumination, the tracer particles were attracted to the gold nanoparticle and trapped. Notably, the direction of migrating particles was always to hot gold nanoparticles regardless of the configuration of gold nanoparticles placed at two opposite sides of the chamber, on the bottom surface of an upper substrate (ceiling) or on the top surface of a lower substrate (floor). The previous interpretation based on thermal convective flow from the bottom to the top and circulating inside the chamber was only applicable to floor configuration and failed to explain our observation for the ceiling. Instead, temperature-induced Marangoni effect at the water/superheated water interface is likely to play a role. This study promoted a better understanding of the driving mechanism in optothermal trapping. Moreover, as an application of the single-particle platform, we showed the photothermal phase separation-induced microdroplet formation of thermoresponsive polymers and the coating of non-thermoresponsive polymers on nanoparticles.

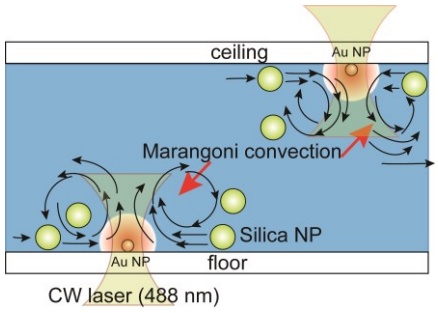

Fig. 1: Concept of single gold nanoparticle-heating-induced transport and trapping of tracer particles. Single Au NP was illuminated with a focused laser beam with a wavelength of 488 nm in silica suspension.

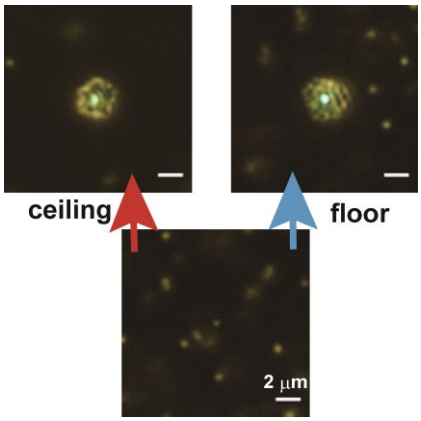

Fig. 2: On illumination, silica particles were attracted to a hot Au NP and trapped. Two configurations, floor and ceiling, gave a similar observation.

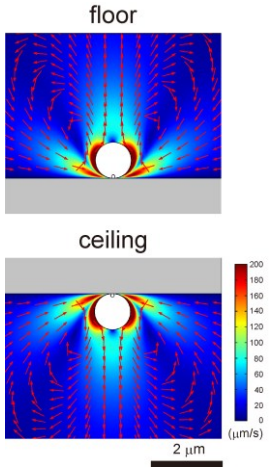

Fig. 3: COMSOL simulation of thermal convection and temperature-induced Marangoni convection around a Au NP surrounded by a photothermal bubble.

[1] Aibara et al., J. Phys. Chem. C 121 (2017) 22496-22507.
[2] Chikazawa et al. J. Phys. Chem. C 123 (2019) DOI: 10.1021/acs.jpcc.8b11575.