Abstract: We experimentally demonstrate the use of random plasmonic nano-islands for optical trapping and assembling of particles and live cells into highly organized pattern with low power density. The observed trapping effect is attributed to the net contribution due to near-field optical trapping force and long-range thermophoretic force, which overcomes the axial convective drag force, while the lateral convection pushes the target objects into the trapping zone. Our work provides a simple platform for on-chip optical manipulation of nano- and micro-sized objects, and may find applications in physical and life sciences.

Figure 1. (a) Thermal convection including lateral motion (1) and vertical motion (2). (b) Near-field optical trapping force (3i). (c) Thermophoretic force pushing the PS particles from cold to hot. (d) Schematic of optical setup for the experiments.

Near-field distribution and optical trapping forces

Figure 2. (a)-(d) Simulated electric field intensity distributions 5 nm above the upper surface of samples S1-S4, respectively. The light source is a plane wave with wavelength of 785 nm and X-polarized electric field. (e) Calculated optical forces exerted on a PS particle (diameter=500 nm) with the gap between the PS and upper surface of AuNIS is varied from 5 to 20 nm. (f) Optical forces versus five random PS positions, with the gap between fixed at 5 nm. (g) Magnitude of optical trapping force versus the experimental laser power densities.

Statistics of trapped polystyrene spheres (PS)

Figure 3. (a)-(c) Statistical analysis of the trapped PS as a function of time and laser power for S1-S3 respectively. Solid lines are the exponential fitting to experiment data. The inset in (a) shows the schematic of the trapping potential well with a Gaussian profile. (d) Convective drag forces exerted on PS during trapping for S1-S3 respectively. The error bars indicate the experimental standard deviations.

Trapping behavior with a tightly focused laser beam

Figure 4. (a)-(d) Frame images of trapped PS assembly on samples S1-S4, respectively. The laser spot has been tightly focused on the sample surface with diameter as small as 1 μm. White bar: 5 μm.

Conclusion: we have proposed and demonstrated the feasibility of using large-scale random AuNIS for trapping and manipulating of PS particles and live Escherichia coli cells with ease. The system can be extended for virology and immunology testing of infected biological fluid samples.

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