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Stable Particle Clusters Trapped and Assembled Using a Plasmonic Nanotweezer Integrated on a Silicon Waveguide

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1. Introduction

Recently, hybrid nanophotonic devices composed of both photonic and plasmonic elements have attracted a lot of interest for on-chip sensing, light emission, and quantum optics applications. [1,2] In this work, we report on the optical trapping, assembly, and self-organization of fluorescent polystyrene beads using plasmonic nanotweezers located on a silicon photonic waveguide. By resonantly exciting the plasmonic mode of a periodic chain of gold nanorods coupled to a silicon waveguide, [3,4] we achieve single particle trapping as well as particle cluster assembly. Based on experimental observations and motion tracking analysis, we investigate the geometry, orientation, and stability of the self-organized bead clusters.

2. Experimental details

Hybrid photonic-plasmonic structures

In this work, periodic chains of 5 gold nanorods (210×70×30 nm^3) are fabricated by e-beam lithography, gold deposition, and lift-off process on a silicon waveguide (500×30 nm^2) after precise realignment of the lithography mask on the silicon photonic chip. Efficient coupling of the infrared laser light (wavelength ~1530 nm) from the waveguide's fundamental TE mode to the plasmonic mode of the plasmonic nanochain enables confining the incident guided light in the near-field of the plasmonic nanochain.

Trapping experiments

A microfluidic chamber is fabricated on the photonic chip by dropping few µL of an aqueous dispersion of fluorescent polystyrene beads (diameters: 390 nm, 500nm, or 1 µm). A laser power of few mW is used to trap and assemble the beads under the action of the enhanced gradient force in the plasmonic nanochain's near-field. Trapping potential maps and trap stiffnesses are measured and analyzed by careful tracking of the trapped beads' motion.

3. Results and discussion

Successful trapping of single polystyrene beads is achieved using a laser power ranging from less than few-hundreds of mW to few mW depending on the bead's size. The measured trap stiffnesses values are of the order of 0.1~1 $fN.nm^{-1}$.

We also observe the assembly of clusters composed of up to nine 500 nm beads. Surprisingly, the orientation and stability of the clusters is found to greatly vary depending on the number and the configuration of the trapped beads. By analyzing of the trapped bead's motion, we show that vacancy-free cluster topologies are the most stables. Our results evidence that the relief created by the waveguide at the surface of the sample and the resulting electrostatic potential barriers at the edges of the waveguide play a key role in the enhancement of the clusters' stability.

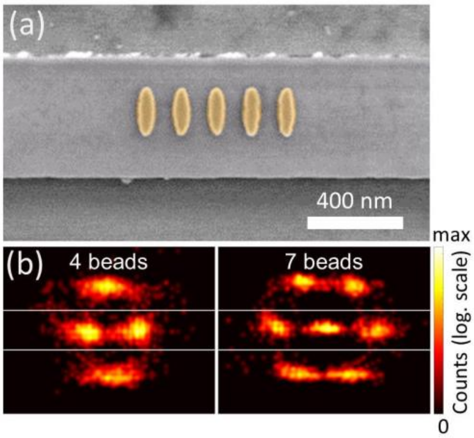

Figure 1 (a) SEM image of a gold nanorod chain fabricated on a silicon waveguide. (b) Spatial distribution of the probability of presence of the trapped beads forming a 4-bead cluster (left) and a compact 7-bead cluster (right).

3. Conclusions

Based on the observation and analysis of optically assembled clusters of polystyrene beads, our results show how stable vacancy-free clusters can be formed through the joint action of optical and electrostatic forces. This work paves the way for further development of plasmonic nanotweezers following a multiphysics approach.

Acknowledgements

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