SHORT COMMUNICATION

Nanoparticle accumulation, directional delivery, and it's release along a nanofiber

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ABSTRACT

A key component of nanoengineering is the controlled accumulation and delivery of nanoparticles (NPs), which is crucial for targeted therapy or the elimination of microorganisms.

The method for accumulating, delivering, and releasing nanoparticles across two optical nanofibers with counter-propagating evanescent waves of 980-nm wavelength (NF). We experimentally and theoretically demonstrate that the NPs delivered along the NF surface in opposite directions are accumulated into the region where the scattering loss of the NPs is maximum, and about 90% of the incident optical field from both ends of the NF can be coupled into the region using a 713-nm-diameter polystyrene NPs suspension and an 890-nm-diameter NF as an example.

By adjusting the incident optical field, the accumulation region can be adjusted.

NPs can be delivered while the two counter-propagating laser beams have a high-power ratio and then by shutting off the two lasers, discharged into the precise spots.

Key Words: *Accumulation of nanoparticles; Directional delivery; Release; Optical nanofiber*

INTRODUCTION

The secret to nanotechnology lies in the manipulation of nanoparticles, particularly large trapping and directional delivery. [1] Numerous techniques, including electrical [2], magnetic, hydrodynamic, and optical force, have been suggested to manipulate micro- and non-particles. Since Arthur Ashkin employed two opposing focused beams to trap particles [3], optical forces have been a productive, non-contact, and non-intrusive method of particle manipulation. However, due to the optical diffraction limit and the fact that the trapping force decreases noticeably as particle size decreases, conventional optical tweezers (COTs) are difficult to use for capturing nanoscale objects [4].

By simply raising the laser power, the optical trapping force can be strengthened to handle smaller particles, although this improvement is quite restricted and results in irreparable photothermal damage. The "sharpness" of the optical intensity gradient can be made sharper or the optical field can be locally amplified [5] to manipulate nanoparticles in stable ways. Many near-field optics-based nanotweezers, including slot waveguide [6], photonic crystal, plasmonic, optical fibre, and other nanotweezers, have been proposed over the past few decades to overcome the COTs' diffraction limit. Among these, optical nanofibe is a more adaptable and practical tool for near-field optical manipulation in very small spaces, with the benefits of longer delivery range and smaller couple loss. A strong optical gradient is created when a laser beam is coupled into a nanofiber because the evanescent field that leaks from the nanofiber decays exponentially along the axis perpendicular to the nanofiber surface. As a result, the strong optical gradient force and optical scattering force can both trap particles interacting with the evanescent field on the nanofiber surface and then propel them forward along the surface.

EXPERIMENT

The experiment's guiding principle is shown in figure 1. An 890 nm-diameter NF was immersed in stationary suspension after being extracted from a single-mode optical fibre used for commercial purposes using the flame heating process. The SEM pictures of the nanofiber with magnifications of 10,000, 100,000, and 200,000, respectively. These images demonstrate good sidewall smoothness and uniformity. The estimated average sidewall root-mean-square roughness is 0.5 nm. The suspensions were made by ultrasonically dilating 713 nm diameter polystyrene NPs into deionized water (1:1000 volume ratio of particles to water) for 30 seconds [7]. Two lasers beam with a wavelength of 980.0 nm produced two laser beams with optical strengths of P1 and P2 that were fired into the NF in opposing directions. This wavelength was selected in this case primarily because it can aid in obtaining a potent evanescent wave outside the NF surface and has a low light absorption for the majority of living stuff. Since the NF, NPs, and water are nearly transparent to light at 980 nm, absorption loss is disregarded. In a perfect scenario, the trapped NPs can either be positioned on the NF surface by adjusting the incident optical power ratio or transported along the surface of the NF in two controllable directions. Non-strictly uniform NPs also have non-strictly uniform delivery velocities. More specifically, larger NPs

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can distribute at greater speeds than smaller NPs can Therefore, the aforementioned two circumstances contributed to the experiment's non-uniform NP delivery velocities, which made it simple for the trapped NPs to link together. The short chain may function as a bigger NP with a faster delivery speed that might keep pursuing the other "little" moving NPs [8]. The position thus creates an accumulation zone where the NPs delivered along the incident optical power ratio of the two incident laser beams can be changed to control the accumulation region. In particular, the accumulation region remains stationary on the NF when = P2/P1 = 1 (where P1, P2 denote the incident optical power of the left and right ends of the NF, respectively) [9].

The right side of the NF will receive the accumulation region when 1, the accumulation region will be transferred to the NF's left side when > 1. That is, the motion direction of NPs in the area of NF where they are accumulating likewise shows the opposite direction with a rising, which is further clarified in the latter simulation. This research shows that by turning off the two lasers, we can achieve the controlled buildup of the NPs, directional delivery, and release to the precise locations [10].

CONCLUSION

The aggregation and transportation of particles to specific areas using an optical nanofiber have been theoretically and empirically proven. 713 nm diameter polystyrene particles were bidirectionally accumulated into the region by launching two counterpropagating 980 nm wavelength laser beams into an 890 nm diameter nanofiber. The accumulation region was controlled by adjusting the incident optical power ratio in the NF. Moreover, by shutting off the two lasers at the appropriate time, the accumulated NPs were released into particular areas. The biomedical and chemical fields are predicted to benefit from the findings.

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