DNA Unzipping by Resonator-Based nSWATs

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Primary CNF Tools Used: ASML deep uUV stepper, Oxford 100 plasma etcher, Unaxis 770 deep Si etcher, Heidelberg mask writer DWL2000, SÜSS MA6-BA6 contact aligner, Gamma automatic coat-develop tool, LPCVD nitride - B4 furnace, wet/dry oxide - B2 furnace, AJA sputter deposition, CVC sputter deposition, GSI and Oxford PECVD, SC4500 odd-hour evaporator, Zeiss Supra and Ultra SEM

Abstract:

A nanophotonic trapping platform based on chip-based tunable optical interference allows parallel processing of biomolecules and holds promise to make single molecule manipulations and precision measurements more easily and broadly available. The Wang lab has developed and implemented such an on-chip device based on Si or Si_3N_4 waveguides, coined a nanophotonic standing-wave array trap (nSWAT), that allows for controlled and precise manipulation of trapped nano/micro particle arrays [1-4]. We present here the latest generation of nSWAT devices that contains the following features: (1) local force enhancement are achieved by a resonator-based design; (2) response time of the phase modulation heaters are drastically shortened by a balanced and differential micro heater design; and (3) the thermal drifts of the whole device due to local heating of micro heaters are diminished by a novel sample holder design and cleaver micro heater re-arrangement. With all these crucial improvements, we have for the first time successfully unzipped DNA molecules on an nSWAT device. This is a benchmark achievement, making the nSWAT devices much more relevant in the single molecule field.

Summary of Research:

Optical trapping is a powerful manipulation and measurement technique widely employed in the biological and materials sciences. Miniaturizing bulky and expensive optical trapping instruments onto optofluidic platforms holds promise for high throughput lab-on-chip applications that can be readily integrated with other novel lab-on-chip innovations such as fluorescent detectors or on-chip lasers.

Recently, we have demonstrated a high-throughput, near-field nanophotonic trapping platform that achieved stable trapping with precision controllable repositioning [1-4]. The core concept of the platform is nanophotonic standing-wave interferometry, where laser light travels through a nanophotonic waveguide, is split into two equal intensity laser beams, the two beams are guided by the waveguides and meet each other, which ultimately leads to interference of two counter-propagating laser beams and results in the formation of standing waves. The evanescent field of the antinodes of the standing wave forms an array of stable three-dimensional optical traps. We call this type of trap a nanophotonic standing-wave array trap (nSWAT). By tuning the phase difference between the two counter-propagating laser beams, the antinode locations can be precisely repositioned, and consequently, the optical trap positions can be precisely manipulated. The nSWAT device holds the capability for high throughput precision measurements on-chip.

In the past year, we have advanced the nSWAT concept in several aspects. (1) We have implemented a resonator-based design for ultimate local intensity enhancement into the nSWAT devcies. Among all designs, this resonator design gives the highest force enhancement factor, limited only by the total scattering loss of the trapped beads onto the waveguide. We have measured around three times force enhancement, larger than our previous force-double design [4]. (2) We have implemented a balanced layout and differential operation mode for the micro heaters. This greatly reduced the response time of the micro heaters (from ~30 μs to ~1 μs). This is shown to be crucial for maintaining high trapping forces for a

trapped bead under strong biased forces under single molecule manipulations. (3) We have also designed a special sample holder for the nSWAT chip that can greatly reduce (by two orders of magnitude) the thermal drift of the sample caused by the micro heaters. This greatly enhanced the thermal stability of the nSWAT devices.

Thanks to the above described improvements, we have achieved DNA unzipping on the nSWAT devices for the first time. We are currently preparing a manuscript on these latest advancements on the resonator based nSWAT devices.

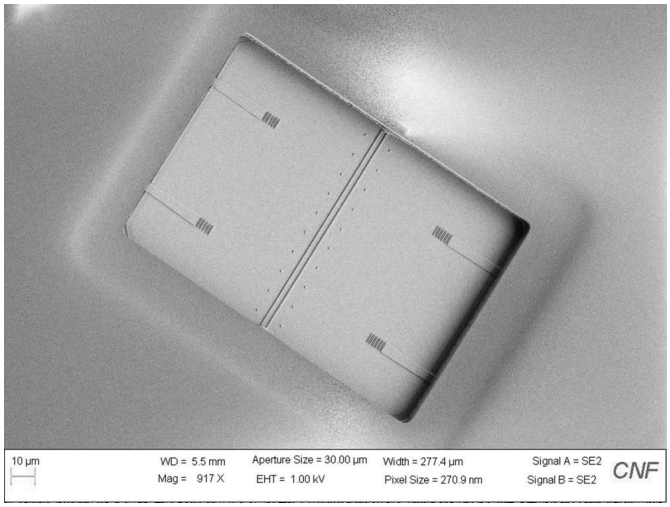

Figure 1: A tilted SEM image of the active trapping waveguides in the fluid pool region (big rectangle) of the latest resonator based nSWAT devices. The two parallel Si_3N_4 waveguides cut through the fluid pool in the middle, with two adjacent arrays of circular dots serving as local fiducial for real time motion tracking for trapped beads. Under operation, two arrays of polystyrene nanospheres (with 380 nm diameter) are trapped onto the two parallel waveguides. DNA molecules attached between two beads on both waveguides can be manipulated and studied by controlling the beads on each waveguide independently. The four wider Si_3N_4 waveguides terminating with free-space coupling gratings are carefully designed local laser intensity indicators for the two trapping waveguides.

References:

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