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Nano-gap fabrication by focused ion beam for DNA trapping

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Abstract

Micromachined tweezers having nanometer sized gap was fabricated with a silicon isotropic etching method and a focused ion beam technique. The gap of tweezers fabricated by this process was accomplished to be 15 nm-2 μm ranges. The validity of this tweezers was demonstrated by trapping DNA molecules. Trapping of bundle of λ-DNA molecules between 100 μm gap was succeeded.

Keywords: Focused ion beam, Nano-gap, λ-DNA, Micromahineing, Molecular manipulation

1. INTRODUCTION

This paper proposes a micromachined tweezers having nanometer sized gap for biological molecular manipulation. The devices were fabricated by silicon micromachining and focused ion beam technique (FIB). The efficiency of the processed micro-device is demonstrated by the trapping of DNA molecules.

The manipulation of biological molecules have recently attracted much attention in the field of life science. As direct physical manipulation permits assays at the individual molecular level. Previously, we reported a micromachined tweezers which was consisted of a pair of opposing probes and integrated a microactuator for changing the probe gap [1]. The tweezers trapped DNA molecules by dielectric field and electro-chemical reaction [2]. This technique is suitable for long molecules (10>μm), therefore, alternative way is necessary shorter ones. Compared to already published nano gap fabrication for DNA analysis [3], this paper highlights the versatility of FIB fabrication in the control the gap size and successful DNA trapping in it.

2. EXPERIMENTAL

The silicon micromachined tweezers were fabricated by anisotropic micromachining technique [1], from (100) silicon on insulating substrate. To obtain nano-gap between the opposite probes, the microtweezers were post-processed with a FIB. The probe gaps were controlled by the gallium ion beam spot location and exposure time. Finally, the surface of probe tips were deposited with aluminium (10 nm layer). The Aluminium layer acts as an anchor material to DNA molecules and is also used as an electrical conductor from electrical pads to probe tips. Processed probes observed by a scanning electron microscope (SEM) are displayed in Fig. 1. To perform the molecular trapping, the tweezer was dipped into a droplet of a solution containing either λ-DNA molecules (48502 bp, 16 μm length) or synthesized DNA molecules (108 bp, 37 nm length) both labeled with YOYO-1 fluorescence dye. An ac electric field (1MHz, 1MV/m) was applied between probes for several seconds to trap DNA molecules. After the trapping procedure, the probes were retrieved from solution, trapped DNA molecules were observed by a scanning transmission electron microscope (STEM).

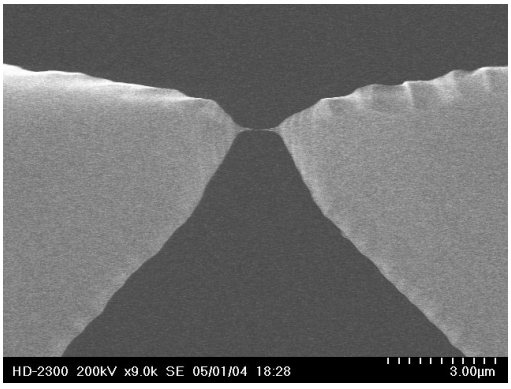

Figure 1. Fabricated probes (FIB processed).

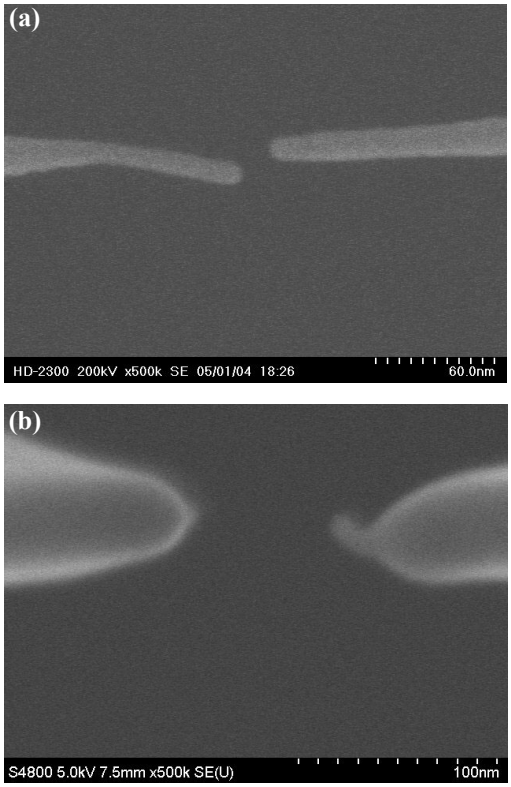

Figure 2. Fabricated nano-gap between opposite probes, (a) 15 nm gap, (b) 100 nm gap.

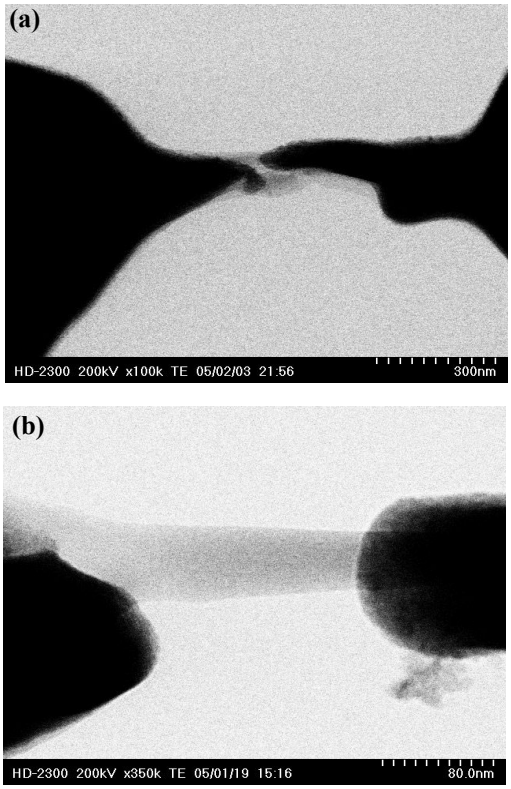

Figure 3. Trapped λ-DNA molecules between the probes, (a) 15 nm gap, (b) 100 nm gap.

3. RESULTS AND DISCUSSION

The gap lengths were indeed easily tuned by controlling the ion beam spot location and exposure time during FIB process. Multiple probes gap widths were successfully processed in the 15 nm-2 μm range, as shown in Fig. 2. The radius of probe tips was approximately 5 nm for the 20 nm gap. The sharpness of probes was verified for all processed device. This sharpness is crucial for the DNA molecules trapping, as electrical field is concentrated between the probe tips when ac voltage is applied.

This characteristic is confirmed by Fig. 3 that shows λ-DNA molecules trapped between processed probes. Although the trapping experiment of synthesized 37 nm DNA molecules between 15 nm gap were conducted, DNA molecules were not observed by STEM. It is supposed that DNA molecules were pull off from the probes during the removal of the tweezers from the droplet, as a result of surface tension or viscosity drag in aqueous solution.

4. CONCLUSION

Described technique has a possibility of trapping and freely manipulation of biological molecule with several ten nano-meter size trapping gap.

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