Stretching and Immobilization of DNA Molecules in Si Channels With Integrated Electrodes

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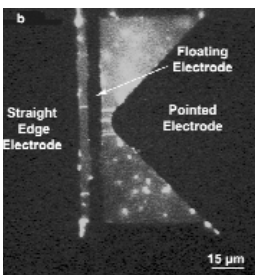
Low-temperature Si-to-glass bonding using polymethylmethacrylate (PMMA) as an adhesive layer is developed to integrate electrodes with Si channels. The integrated microsystem contains channels dry etched in Si with widths ranging from 3μm to 100μm and depths ranging from 100nm to 30μm. The channels are bonded to a 100μm-thick glass consisting of 600nm-thick patterned PMMA and 20/50nm-thick Cr/Au electrodes, with PMMA as an adhesive layer. The typical bond strength is 3MPa, obtained by bonding at 110°C with 600nm-thick PMMA. Fluidic flow studies are carried out in channels that are 50μm and 100μm-wide with a depth of 100nm. Deionized water flows through the sealed Si channels due to capillary pressure with an initial velocity of 0.65mm/s for 50μm-wide and 100nm-deep channels. Electric fields are used to induce deoxyribonucleic acid (DNA) motion with velocities from 2.4μm to 14.5μm/s in 100μm-wide and 20μm-deep channels. The forces generated by the fields and the fluid flow are also used to stretch the tethered DNA molecules up to 1 5μm long in the microchannels. A technique called "protein-assisted DNA immobilization" (PADI) is developed to immobilize and stretch, but not overstretch, DNA molecules inside a micro/nanochannel with limited surface interactions while maintaining continuous hydration at physiological pH. The biological activity of the immobilized DNA molecules is confi rmed by digesting the DNA with restriction enzymes in the microchannel. Single-molecule transcription, which has stringent requirements on the immobilized DNA with respect to surface interactions and stretched lengths, is also successfully demonstrated on DNA molecules immobilized by PADI. In addition to arraying DNA molecules for study of DNA-protein interactions, the immobilization method could be used to construct DNA-templated nano-electronic devices. Control over the placement of stretched DNA molecules in a microfluidic system is a critical requirement for molecular nanotechnology. A technique is developed where a large number of DNA molecules can be immobilized specifically at one end to the electrode tip and stretched in a microchannel using high-frequency ac fields. λ-DNA molecules are immobilized and stretched using 100kHz ac fields in a 100μm-wide and 75μm-deep Si microchannel. Using a floating electrode in between two biased electrodes, stretched T2 DNA molecules are immobilized across a 5μm-wide electrode gap by electric field and hydrodynamic flow. This project is supported by the National Science Foundation under award number NSF-NIRT 0304316.



Using a floating electrode in between two biased electrodes, stretched T2 DNA molecules remain immobilized and stretched across a 5µm-wide electrode gap after electric field and hydro-dynamic flow are turned off.