Integrated Nano Electromechanical System for Single Molecule (DNA) Trapping and Characterisation

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Abstract

The objective of this project is to demonstrate, for the first time, the single molecule manipulation and characterization by micromachined silicon based tweezers. DNA strand being the targeted molecule. Molecule isolation is performed thanks to microfluidics circuits and DNA bundle has been successfully trapped by immersed tweezers.

I. Objective

The need for a controlled handling and manipulation of single molecules has drastically increased over the past years due to the enhanced interest for the exploration of the physical properties of biological systems and molecular electronics devices. Besides near field spectroscopy, a variety of techniques such as electric, magnetic and optical traps have been used to position and characterize nano-scale objects and molecules [1,2].
Beyond these important basic physical investigations, a huge interest exists now move towards more systematic analysis and real biological and medical applications.

To achieve this expected applicative goal, the micro-nano-system (MNEMS) concept has to be exploited as it can combine very accurate molecular level engineering tools with integrated highly parallel, reproducible and controllable processes. But single molecule capture and manipulation by MNEMS have not been demonstrated yet, due to a lack of control of the integrated tools. Once overcome, this direct manipulation capability has the potential to bring a drastic change in bio technology by replacing statistical method like test tube by direct assay at the single molecule level [1].

So, this research project aims to contribute to the *first demonstration of the direct molecule isolation and characterization with a MEMS actuator*, DNA strand as targeted molecule.

II. Strategy

The integrated approach for DNA isolation, trapping and manipulation is depicted in fig. 1. DNA molecules are introduced in a microfluidic chip and are moved by DC electrophoresis. A nanochannel separates and isolates the molecules that are finally trapped by a MEMS tweezers in the capturing well. Ac signal applied between the opposing tips allows to extent position and trap the molecules between them [1].

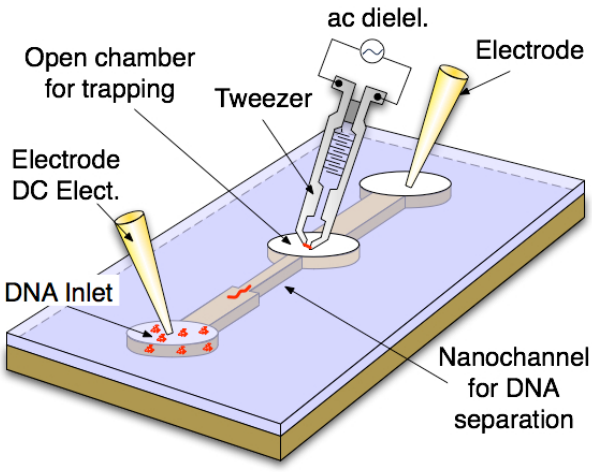

Figure 1: Molecule isolation and trapping

To capture the single molecule, 3 preliminary objectives have been identified:
- obj1 : proof : Isolation and trapping of DNA with a microfluidic circuit with fixed electrode
- obj2 : Capture and validation of the single DNA trapping by the immersed tweezers
- obj3 : Control of the DNA motion and isolation in the channel through Coulter effect (change of the nanochannel impedance through the presence of the DNA molecule).

Beyond these basic milestones, single molecule manipulation and characterization during assays will be performed as real objective of this project.

III. Preliminary results

The preliminary results mainly concerns the first 2 objectives : Fig. 2 presents the DNA isolation by microfluidic channel and attraction of DNA molecules on fixed electrodes. The complete trapping have not been achieved yet, as hydro dynamic flow (EHD) induced by the DEP prevents to stabilized the DNA between the electrodes. New generation of device with optimized electrodes topology are under investigation.

Fig. 3 presents fabricated tweezers (electrostatic actuation and capacitive displacement read-out) and successful trapping of a bundle of DNA between their opposing tips [3].

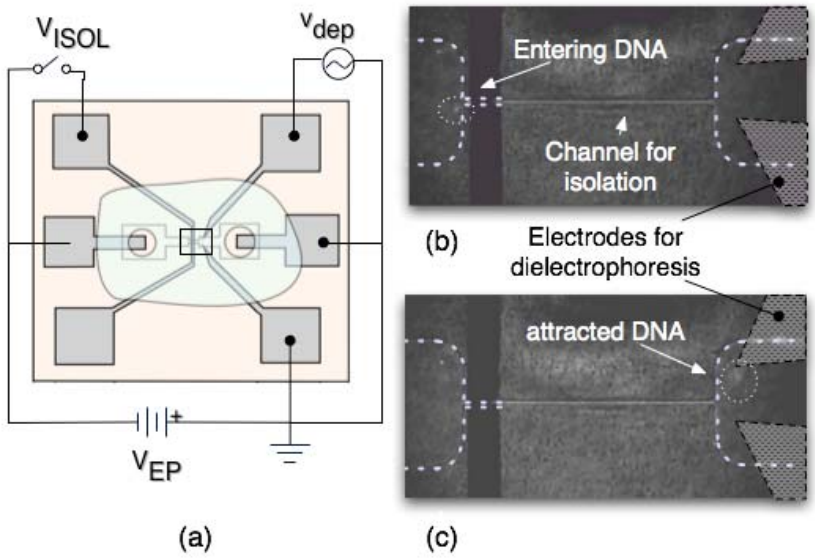

Figure 2 : Microfluidic chip (a) schematic of the chip with inlet/oulet and bias. Enlarged view of the chip center with (b) DNA entering in the channel and then (c) attracted by DEP.

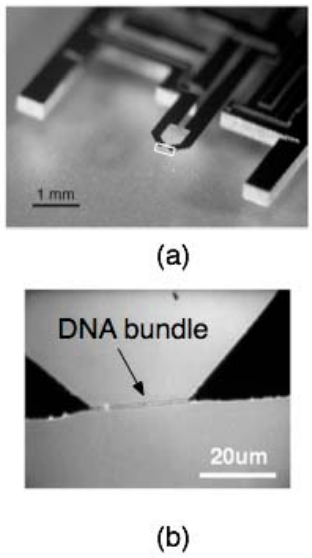

Figure 3 : tweezer. (a) processed device. (b) trapped DNA bundle.

These partial results illustrate our step by step strategy that will be pursued to tackle the overall project objectives mentioned above.

Acknowledgments

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