Nanostructured, Active Electrostatic Trap for Confining Nanometric Objects in a Fluid: *mimicking DNA-Protein interactions in a synthetic system*

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In living cells, sensing and actuation is carried out at the nanoscale with great efficiency and precision. One of the most powerful of such systems is the transcription of DNA into RNA. It is believed[1] that the interaction between the cationic residues on the protein enzymes and the negative charges on the phosphate groups of the DNA is primarily electrostatic in nature and 1-dimensional nanostructure play a key role. The current study encompasses the first steps in creating a synthetic, engineered system that can mimic the physiological DNA-Protein enzyme interaction using non-biological nanostructures. Many research groups[1,2] have proposed that once the protein enzyme is localized near the DNA structure, it slides and hops around until it finds its intended target sequence. This translates to trapping/de-trapping and 1-dimensional diffusion of nanometric objects, in a synthetic system. Charge on the DNA, charge on the protein, relative sizes (sub 10nm) and the physiological ionic strength (100mM) of the interacting medium play a key role and the interaction is favorable only when these parameters strike a balance. Therefore, in our synthetic system, we realize the DNA as metallic line charge (+ve) and the protein as a charged nanoparticle (-ve). Our experimental setup is based on creating a tunable, spatially modulated electrostatic potential profile near a nanoscale metal line charge (sub 30nm) by biasing it against a counter electrode, in an aqueous solution. The system consists of a microfluidic channel between two fluidic slit surfaces, that acquire an equal and opposite charge when biased using a potentiostat(Figure 1: a.). One surface consists of a nanoline pattern topographically structured by using electron beam, nanoimprint, and focused Ion beam techniques as shown in the Figure 1: b. Charged, fluorescent, polystyrene nanoparticles (40-400nm) are being studied for their interactions. Epi-fluorescent and TIRF microscopy were used to capture the surface interactions. On application of a voltage bias across the two electrodes (0 - 4V), a positive charge is created on the Au nanoline which then attracts the negatively charged particles from solution electrostatically. It has been seen that the particles from the free solution drift towards the voltage biased metal line, line up and undergo localized facilitated diffusion similar to the biological interaction (as shown in Figure 1: c). The magnitude of applied voltage and the ionic strength of the solution control the strength, range and directionality of these interactions. By reversing the polarity, it was seen that the attracted particles desorb as the force changes from attractive to repulsive. A comprehensive theoretical model is established to explain this behavior. Our experiments demonstrate that 1-dimensional nanostructures, when charged, pronounce electrostatic interaction and reduce non-specific interactions. Also, since most materials acquire a surface charge in solution, this setup allows for a single active trap which can be used for confining different molecules as it is material independent and relies on the charge on the molecules.

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[1] *Biochem. Soc. Trans. (2009) 37, 343–348; doi:10.1042/BST0370343; Stephen E. Halford*
[2] *Nucleic Acids Research, 2004, Vol. 32, No. 10; Stephen E. Halford* and John F. Marko*

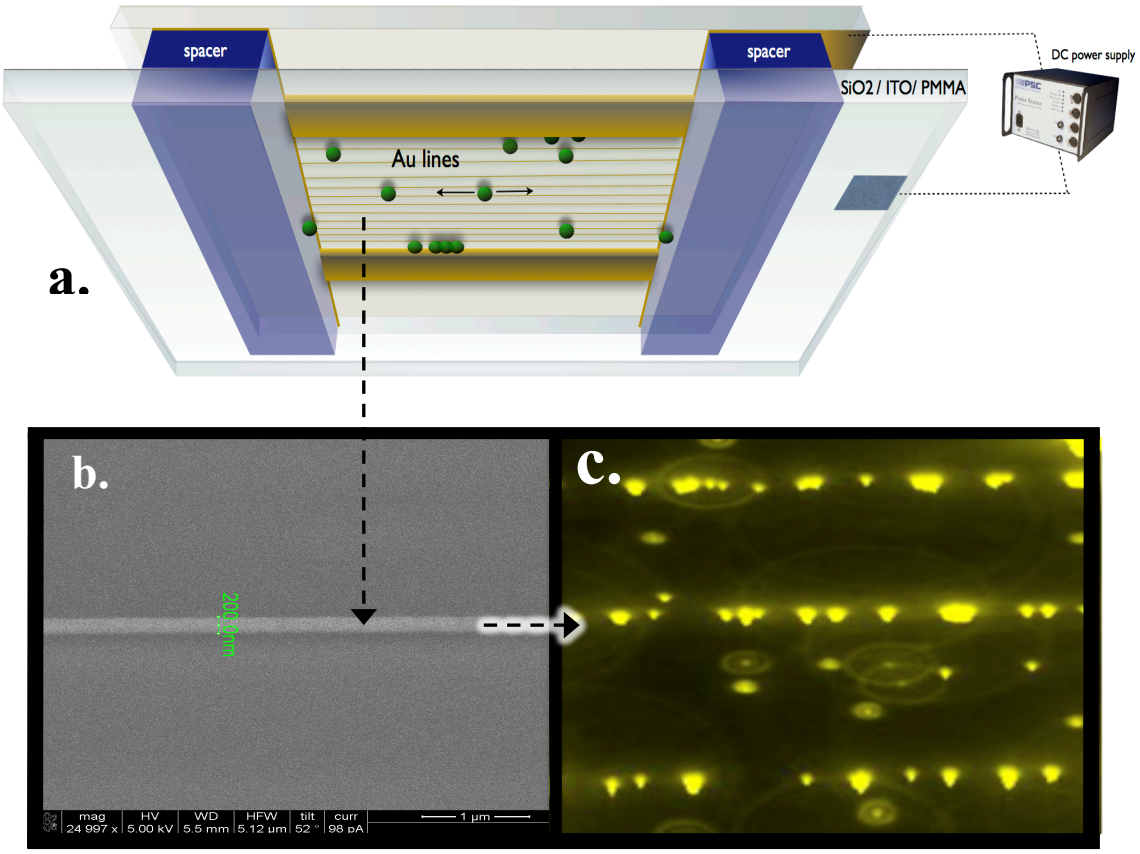

Figure 1: a. Experimental setup - shows the microfluidic cell with the Au nanolines and the nanoparticles. b. SEM image of 200nm Au nanoline. c. Flourescence micrograph of nanoparticles diffusing on a 30nm Au line.