Sensors and Materials, Vol. 21, No. 2 (2009) 105–115
MYU Tokyo

S & M 0752

DNA Separation Chips Using Temporally Asymmetric Ratchet Effect in Nonuniform Electric Fields

Soyeon Yi and Young-Ho Cho*

Digital Nanolocomotion Center
Department of Bio & Brain Engineering,
Korea Advanced Institute of Science and Technology
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Republic of Korea

(Received September 3, 2008; accepted December 24, 2008)

Key words: bio-separators, electrophoresis, DNA ratcheting chips, nonuniformly distributed asymmetric electric fields

We present DNA separation chips using the temporally asymmetric ratchet effect in nonuniform electric fields. The present separation chip redistributes DNA within a specific area in asymmetrically switched nonuniform electric fields based on the size- and field-dependent nonlinearities of DNA drift velocity. Compared with the conventional electrophoresis chips, the present separation chip can be easily integrated into automated DNA analysis systems because of its simple structure and starting-point-independent DNA separation. On the basis of the drift velocity of three different DNA molecules (11.1, 15.6 and 48.5 kbp), we extract the asymmetric alternating electric field conditions ($E_1 = 4E_2$ and $23T_1 = 3T_2$), where Phagemid DNA (15.6 kbp) shows zero net velocity while EM3 DNA (11.1 kbp) and λ DNA (48.5 kbp) migrate to the $-x$ and $+x$ directions, respectively. The present chip is composed of a tapered channel to generate nonuniform electric fields, a DNA loading slit, and a pair of electrodes to apply the electric field. We focus on the design of the DNA separation chips to identify the nonlinearity of DNA drift velocity using three different DNA molecules in the chips. It is demonstrated that different sizes of DNA show different net migration velocities under the nonuniformly distributed asymmetric alternating electric fields. Phagemid DNA moved to its own specific location, −1.5 mm from the starting point (+2 mm from the loading slit), then showed zero net migration velocity. Other sample DNA molecules, EM3 and λ DNA, migrated 2.2 mm in the $-x$ direction and 1 mm in the $+x$ direction, respectively, under the alternating asymmetric electric field, toward their own specific locations where they show net zero velocity. Also discussed are the potentials of the present DNA chips for the miniaturization of DNA analysis systems and the potentials of the present DNA chips having tunable capability of the target DNA size to be separated.

*Corresponding author: e-mail: nanosys@kaist.ac.kr