DYNAMICS OF NANOELECTROKINETIC SELECTIVE PRECONCENTRATION

Sung Jae Kim[1,*]
[1]Department of Electrical and Computer Engineering, Seoul National University, Seoul, Korea

*Email: gates@snu.ac.kr; Tel.: +82-2-880-1665

In this presentation, an efficient sample preparation process utilizing an ion concentration polarization (ICP) phenomenon would be introduced, especially the simultaneous operation of separation and preconcentration and detailed dynamics of the preconcentrated analytes. ICP is traditional electrochemical ion transportation process and appears as a steep concentration gradient near nanoporous membrane under dc bias [1, 2, 3]. The major function of ICP is an active ion control by an external electric field so that it is significantly useful to study the new ion transportation through nanoporous junction (or membrane) and develop novel engineering applications [4, 5, 6].

Here, we would like to introduce a device as shown in Figure 1 performing selective preconcentration and online collection of charged molecules with different physicochemical properties based on ICP. The device allows subsequent processes of the highly preconcentrated and separated molecules on-chip or off-chip in a single solution. The molecules were highly preconcentrated at each equilibrium position balanced between electroosmotic drag force and electrophoretic force. By the repeated chamber geometry, the ion depletion zone was stabilized and the plugs were well-defined. For subsequent on-chip or off-chip application, pneumatic micro-valve system was integrated. The successive operation of selective preconcentration and valve operation would recover target molecules at the preconcentration factor more than 30 as shown in Figure 2.

Furthermore, we investigated the detailed spatiotemporal dynamics of preconcentrated analytes for multiple analyte mixture. In the case of single-analyte preconcentration, there were two distinct regimes: staking and propagating regime as shown in Figure 3. Meanwhile, the equilibrium position of the plug was shifted in the case of multiple analyte preconcentration due to electrokinetic intermolecular interactions. A critical mobility was extracted for determining the types of preconcentration and it was confirmed both by experiment and numerical simulations as shown in Figure 4.

These results would play a key role in enhancing accuracy of practical ICP applications through elucidating comprehensive preconcentration mechanisms which are critical in analytical systems such as diagnostics, biology researches, and point of care systems.

Word Count: <= 500

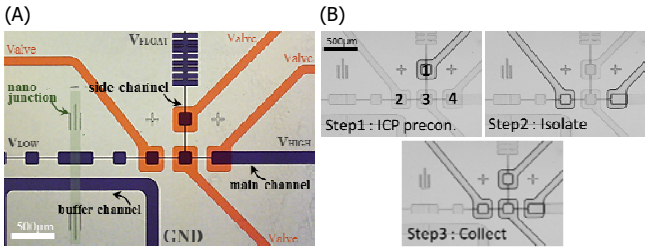

Fig.1 (A) Microscopic image of the device and (B) three steps of valve operations, consisting of an ICP preconcentration step, a plug isolation step, and collecting step.

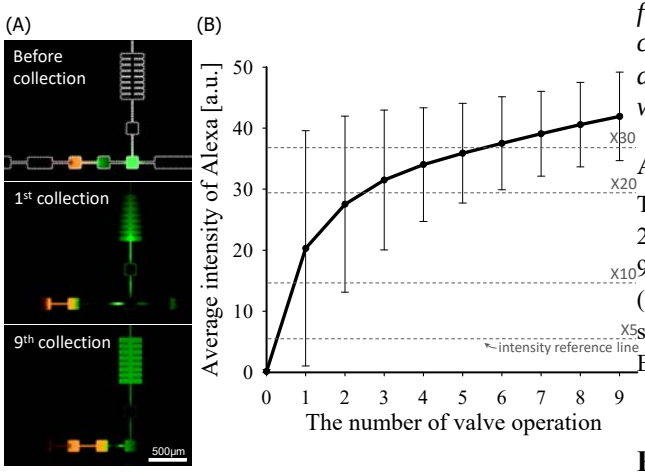

Fig. 2 (A) Time-lapse images of repeated valve operations collecting selectively preconcentrated plugs and (B) mean intensity change in the measurement window over number of repetition of valve operation. Note that there is no SRB in the measurement window.

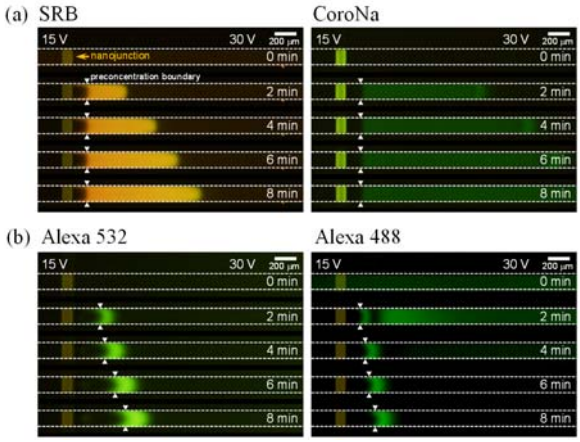

Fig. 3 Time-lapse images of each preconcentration behavior of (a) SRB and CoroNa (stacking regime) and (b) Alexa 532 and Alexa 488 (propagating regime). Two opposite white triangles designated the preconcentration boundary of each analyte.

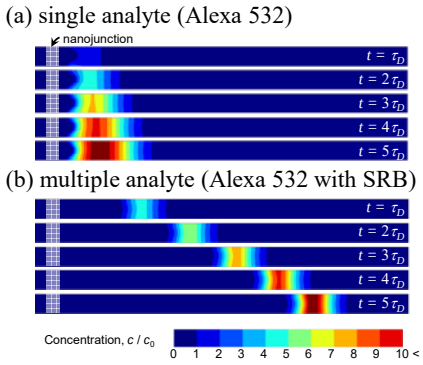

Fig. 4 Spatiotemporal dynamics of preconcentration for relatively high mobility sample (Alexa 532) in the case of (a) single analyte solution and (b) mixture of analytes with low mobility (SRB). In each figure, τ_D was diffusion time scale.

AKNOWLEDGEMENTS

This work was supported by NRF (CISS-2011-0031870, 2012-0009563,2016R1A1A1A05005032,2016R1A6A3A11930759) and Korean Health Technology RND Project (HI13C1468 and HI14C0559). All authors acknowledge the support from BK21+ program of Creative Research Engineer Development IT, SNU.

REFERENCES:

[1] Cho et. al., "Non-Negligible Diffusio-osmosis inside an Ion Concentration Polarization Layer," ***Physical Review Letters***, 116, 2016, p254501

[2] Nam et. al., "Experimental Verification of Overlimiting Current by Surface Conduction and Electro-osmotic Flow in Microchannels," ***Physical Review Letters***, 114, 2015, p114501

[3] Kim et. al, "Concentration Polarization and Nonlinear Electrokinetic Flow Pattern near Nanofluidic Channel," ***Physical Review Letters***, 99, 2007, 044501

[4] Kim et. al, "Direct Seawater Desalination by Ion Concentration Polarization," ***Nature Nanotechnology***, 5, 2010, p297

[5] Park et. al., "Capillarity Ion Concentration Polarization as Spontaneous Desalting Mechanism," ***Nature Communications***, 7, 2016, p11223

[6] Son et. al., "Engineered Nanofluidic Preconcentration Devices by Ion Concentration Polarization," ***Biochip Journal***, 10(4), 2016, p251