CONTINUOUS CONCENTRATOR FOR NANOPARTICLE BASED ON CASCADE AC ELECTROOSMOTIC FLOW

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ABSTRACT
We present an efficient and versatile on-chip continuous concentrator of nanoscale samples using improved cascade alternating-current electroosmotic flow (cACEO). A multistage electrode consisting of chevron and double-gap geometry was embedded on a chip to perform an efficient 3D particle focusing. The optimized cACEO overcomes the limitation of particle size and concentrates nanoparticles regardless of properties of the particle due to the fluidic-based principle. As a result, continuous concentration of 50 nm gold nanoparticle with 3D concentration factor over 100 was achieved.

KEYWORDS: cascade alternating-current electroosmotic flow (cACEO), nanoparticle, particle concentration

INTRODUCTION
A particle concentration technique of nanoscopic metal particles is useful for sensitivity enhancement in environmental analysis and medical diagnostics. An electrokinetic particle concentrator based on dielectrophoresis (DEP) has a limitation of target size in microscopic domain due to the volume dependent DEP force acting on the particle [1] instead of the compatibility with microfabrication and integration with sensing elements. An alternating-current electroosmotic flow (ACEO) has a great advantage over other electrokinetic methods of particle manipulation because of its relatively low sensitivity of the particle size due to the fluidic-based mechanism of particle transportation so that it has a potential for nanoparticle handling method. We have developed a novel nanoparticle concentrator by improved cascade ACEO (cACEO) [2] to reduce the applicable particle size to nanoscopic domain and to perform continuous 3D concentration of nanoparticles.

EXPERIMENTAL
The cACEO nanoparticle concentrator consists of an optimized two-stage electrode made of indium tin oxide (ITO) with a thickness of 90 nm to perform the improved concentration of particles; chevron (CH) and double-gap (DG) geometries were serially used as shown in Fig. 1. The combination of ACEO induced by CH and DG electrodes was designed to overcome the size limit of the previous concentrator [2]. ACEO induced around CH was effective to concentrate gradually all particles in a channel to the central part, and that around DG focus gently-concentrated particles to the surface at the center. The chevron design with 50 μm wide line and 25 μm space having 30 degree inclination was optimized for nanoparticle concentration based on 3D flow measurement by micro-PIV. The channel was 500 μm in width, 50 μm in height and 50 mm in length. Samples for concentration were polystyrene nanoparticles (PsNPs) and gold nanoparticle (AuNPs) 50 nm in both diameters.

RESULTS AND DISCUSSION
ACEO generates 3D flow transporting suspended particles to an electrode surface depending on the electric field strength [3]. Concentration of PsNPs was obtained applying a voltage of 6 Vpp and frequency of 100 Hz as in Fig. 2. Fig. 3 shows depth-averaged horizontal concentration factor (CF) evaluated from the fluorescence of PsNPs. CH provides gentle concentration of PsNPs around the center of the channel, while DG concentrates particles to the center and two intermediate regions, indicated Peak A and B, respectively. The peak B showed a weak concentration close to the ceiling by counter ACEO flow. Peak C near the sidewalls is owing to the other counter ACEO [2]. The horizontal CF in the
cACEO reached 3.4, which was improved by 50 % compared with the single use of CH or DG. Furthermore, vertical CF close to the bottom wall of the channel exceeded 2.9. As a result, local 3D CF of 9.9 was attained as shown in Fig. 4.

Fig. 5 a) indicates Au Ps concentration visualized by the plasmonic absorption imaging using 550 nm light. The peak absorption representing high concentration of Au Ps showed strong voltage dependence as in Fig. 6 a). Based on the standard curve of the plasmonic absorbance, concentration of Au Ps achieved the CF of 38. Considering that the vertical CF similarly to Ps Ps, the local CF of Au Ps can be estimated to be over 100.

Figure 2: Concentration of 50nm PsNPs. Depth-averaged fluorescent intensity for particle concentration by a) the chevron, b) double-gap and c) cACEO electrode.

Figure 3: Concentration factor of PsNPs in horizontal distribution in different electrode patterns.

Figure 4: Concentration performance of 50nm PsNPs in cross-sectional particle distribution in cACEO device. PsNPs were focused to the vicinity of the surface electrode at the center of the channel. Intensity was obtained from fluorescence from PsNPs and normalized on the basis of that in no-voltage condition.
CONCLUSION

A novel continuous nanoparticle concentration by using cascade AC electroosmotic flow was demonstrated. cACEO concentrator made both horizontal and vertical concentration of PsNPs on the electrode surface at the center of the channel and its 3D concentration factor reached 9.9. Additionally, highly efficient concentration performance for 50 nm AuNPs with 3D concentration factor over 100 was confirmed. The cACEO-based particle concentrator overcoming the size limit of the conventional electrokinetic concentrator paves a novel application path of sensitive detection and extraction of wide range of nanomaterials.

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REFERENCES


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