Rapid Formation of Colloidal Crystal Patterns in Soft-centrifugal Microfluidic Chips

원심미세유체소자를 이용한 콜로이드 결정 패턴의 고속 성장

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Recently, it is well known that the colloidal crystals can be used for various purposes incluidng optical waveguides, chemical sensors, microfilters, macroporous matrix of catalysts and microdisplays originated from their ordered structure and structure induced photonic band-gap properity. Many reseachers have developed several clever ways to fabricate colloidal crystals based on self-assembly process. However, those process are also based on the evaporation of the solvents, and the crystallization costs very long times. [1]

In this paper, we described a rapid crystallization process for the generation of high quality colloidal crystals inside of the microchannels by using centrifugal microfluidics platforms. Following the conventional fabrication method, we made the centrifugal microfluidic chips. Centrifugal force promoted the crystallization process by excluding solvent rapidly, and the monodisperse silica and polystyrene particles were quickly packed into face centered cubic lattice.

Master patterns of microfluidic channels were created by using the negative photoresist, SU-8 (SU-8 25, MicroChem) on the silicon wafer. Accroding to the conventional reported fabrication methods about soft-microfluidic chips, the polydimethylsiloxane (PDMS 184-A, B, Dow Corning) molds were created. Where, we mixed 184-A (monomer) and 184-B (cross-linker) with the ratio of 4:1, instead of conventional 10:1 ratio, to increase the stiffness of resulting channels and cells. 4-inch glass wafer (1137 1.1T , Corning) was used as a substrate and washed with acetone, isopropanol and ternary distilled water under sonication for 5 minutes each. After oxygen plasma treatment of both PDMS mold and wafer surfaces, they were bonded together and anealed in the 90 °C oven for an hour. Finally, fabricated microfluidic chips were checked by an inverted optical microscope (TE2000, Nikon). Collodial suspensions were injected to the reservior of centrifugal microfluidic units and the capillary force sucked it up owing to the hydrophilcity of inner channels after oxygen plasma treatment. Only the terminal region of the channels were opened to the air because the intakes were sealed after injection. After injection of the colloidal suspensions into the fluidic chip, we just leaved it on the table to crystallize particles at the end of channels. The partially cystllized zone at the end of channels played a role of nanofilters and it prevented escape of colloidal particles from the channels and only the solvent could be excluded during high speed centrifugation. For 30 minute centrifugation at 800~1500 rpm, colloidal particles were completely crystallized inside of the microfluidic channels and cells. For the polystyrene particles, colloidal crystals were also formed at 1000~1500 rpm for 45 minutes. Commercial spin-coater was used to apply

centrifugal forces to the microfluidic units.

When we rotated the centrifugal microfluidic chips, there are two forces which were applied to the colloidal suspension inside the channels. Centrifugal force is working outward and condense the colloidal particles by sedimentation while excluding the solvent to the outside of the channels. Centrifugal force is varied with applied rotation velocity like the following expression of equation (1).

$$\Delta P_C = \rho\omega^2 r\Delta r \qquad (1)$$

Where ρ is suspension density, r is the distance from center of ratation to center of fluid mass, Δr is the radial extent of suspension by applied centrifugal force, ω is the angular frequency of rotation. On the contrary, capillary force is exerted on the suspension inward as represented in equation (2).

$$\Delta P_S = (4\gamma / d_H) + b \qquad (2)$$

ΔP_S is governed by the surface tension, ɣ, of the suspension, hydrodynamic diameter, dH, and constants a and bthat depend on geometry and wettability of the channels. As rotating velocity is faster and faster, ΔP_C is increased and balanced to the ΔP_S, at some radial frequency. When the radial veloicity is increased over the threasold value, ΔP_C exceeds ΔP_S and the suspension in the channel flows outward. Only solvent could escape from the fluidics channels, because we had made pre-crystallized zone at the end of the channels with 500 μm length. Solvent could pass through the interstices among the spheres while the particles were filtered and stacked. Figure 2. shows colloidal crystal patterns created by centrifugal crystallization in microfluidic channels.

We developed a time-saving process for colloidal crystallizations inside of microchannels by using centrifugal microfluidics solutions. Centrifugal force promoted the sedimentation and the silica and polystyrene building-block particles were quickly crystallized into face centered cubic lattice. As we flowing various solvents thorough the colloidal structures, we detected the optical signals with the values of refractive index mismatch between colloidal crystal particles and solvents.

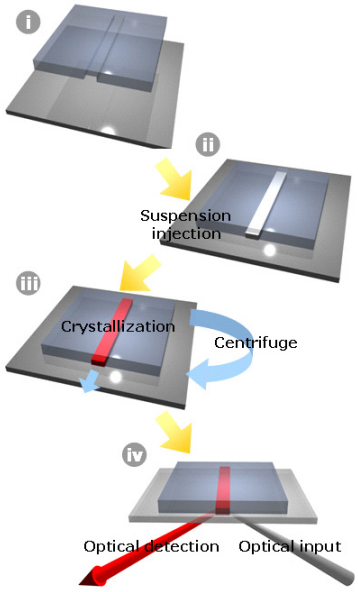

figure 1. schemes for centrifugal microfluidic chip

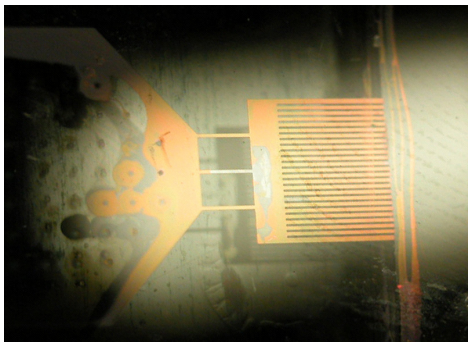

figure 2. photograph of patterned colloidal crystals in centrifugal microfluidic chip