전기수력학적 분무를 이용한 단분산 액적의 제조

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Monodisperse drop formation by electrohydrodynamic spraying

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INTRODUCTION

The uniform-sized droplets are applied for the productions of metal nanoparticles by electrospray technique with differntial mobility analyzer equipment[1], micro/nano size encapsulation by electrified coaxial liquid jets[2], micron-size polymer particles by piezoelectric gnerator[3], hollow silica spheres by dual nozzle[4], monodisperse ordered supraball, which is spherical assemblies of polymer colloid, by water in oil emulsion method[5]. Three-dimensional (3D) assemblies of submicrometer monodisperse colloids have received much attention recently, prmarily because of their potential uses as photonic crystals[6,7].

The electrospray technique is one of the few known aerosol atomization methods which are capable of atomizing a liquid into ultrafine droplets. If an electric potential sufficiently high is applied to the capillary tube, the liquid meniscus at the capillary outlet takes the shape of a cone from whose tip a very thin liquid jet emerges in the so-called cone-jet mode of operation (Cloupeau and Prunet-Foch, 1989). The microjet breaks by varicose wave instabilities into a stream of charged droplets, which eventually disperse into an electrospray. The electrospray is very simple to operate and if operated in the cone-jet mode, it consists of droplets of monodisperse size distribution. Because of the high surface tension of water, the establishment of stable sprays required the use of a sheath flow of CO_2 to prevent breakdown in the gas surrounding the spray and its destabilizing consequences on the electrospray performance[8]. And the flow of CO2 prevent corona discharge at the tip of the capillary. But in case of A.C. electric field, monodiserse droplets were formed one by one synchronously with each cycle change of applied potential in the dripping mode[9]. The sprayed droplets have a net surface charge, which cause the droplets to self-disperse and prevents any droplet agglomeration[10]. It is because the droplets experiences an axial motion by external electric filed and a radial motion by the space charge field.

Here, we generated uniform water drop and monodisperse supraball which is spherical assemblies of polymer colloid by electrohydrodynamic(EHD) spraying technique under A.C. or D.C electric field. Our supraballs were micron-sized colloidal assemblies with narrow size distribution and an ordered internal structure consisting of monodisperse latex particles. The droplet shape and size were measured by optical microscope or transmisson microscope and the structures of their dried particles were observed by scanning electron microscope.

EXPERIMENTAL

The experimental apparatus is shown schematically in Fig 1. The fluid was introduced into the needle(N) by constant pressure through mass flow controller. An electric voltage was applied between the needle and the earth electrode which was a copper plate with a hole for the formed droplets to pass through. In order to observe the fluid issuing from the needle, a CCD system with a microscopic lens was used.

A.C. field

The capillary tube had an outer diameter of 310㎛, the liquid injection pressure was maintained at 0.2 psi and the flow rate of CO_2 was 1L/min. The size and size distribution effect of the formed water droplet were tested by varying the electrical potential and the frequency of the a.c. sin wave. The electric potential applied to the needle ranged from 0 to ±2 kV/cm, and the frequency did from 20 to 120Hz. The liquid were distilled water and 1wt% polystyrene latex.

D.C. filed.

We used three different radius diameter needle and the liquid flow rate was varied by air injcetion using pressure controller from 0 psi to 6.5 psi. And the flow rate of co-axial CO_2 was maintained at 1L/min, the applied voltage was changed form 0kV to 20kV by high voltage power supply. The stable cone-jet mode domains were analyzed by varying the electrode gap ,which is from 2㎝ to 5㎝, and and the liquid flow rate.

Observations of the fluid discharge from the capillary needle were conducted by CCD system with optical microscope. To analyze the size of water drop using optical microscope, we stabilized it in the form of W/O emulsion with the water insoluble and non-ionic surfactant Span 80 (2.0% w/w in mineral oil). And the polymer supraball is analyzed by optical microscope and scanning electron microscope(SEM).

RESULT AND DISCUSSION

Under a.c. electrical potential field with sinusoidal wave pattern, the applied voltage divided by electrode gap and frequency for the formation of monodisperse water droplets was listed in table 1. It also showed that their sizes were a few hundreds micrometer. The size distribution of droplets was monodisperse and their optical microscope images were in Fig2. The effect of electrical voltage on size was shown in Fig2 and Fig3. As the voltage increased, the size of droplet was decreased. The sizes of supraball, which was made with polymer latex, were measured after drying, so their sizes were smaller than water droplets under similar electrical conditions. Under d.c. electrical potential field, the stable cone-jet mode domain was analyzed in Fig 4. In the stable con-jet mode domain, it was easy to produce monodisperse droplets in the lower liquid flow rate region. Although the voltage range was more wide in the high liquid flow region, monodisperse droplets could be produced in the low liquid flow region. The SEM image in Fig4. was supraball obtained in the cone-jet mode at low liquid flow region. During the evaporation of water in the droplets, there is a rearrangement of the PS particles confined to spherical drop.

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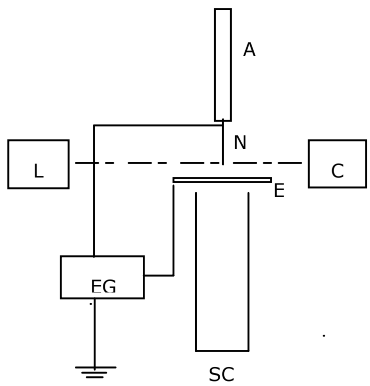

Fig1. Experimental apparatus. N: capillary needle, A: capillary adaptor, L: illuminator, E: electrode plate, EG: electric field generator, SC: sample collector, C: CCD camera with microscope

	±1.5kV/cm	±1.7kV/cm	±2.0kV/cm
60Hz	662µm	542µm	512µm
80Hz		452µm	
100Hz			421µm

Table 1. Conditions of monodisperse water droplet formation.and their size in sinusoidal wave function a.c. filed

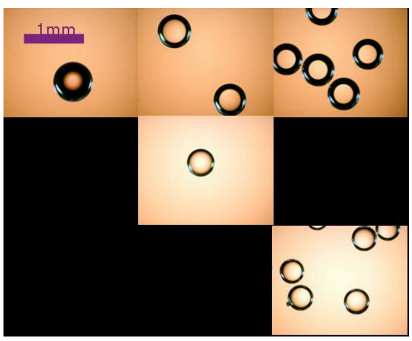

Fig 2. Microscope image of monodisperse water droplets. Their conditions are listed in table 1.

Fig 3 . Monodisperse Supraball at a.c. sine wave with 120Hz frequency and (a) ±1.59KV (88㎛), (b) ± 1.63 KV(83㎛) potential. (The scale bar is 400㎛). The supraballs were made with 1wt% PS latex.

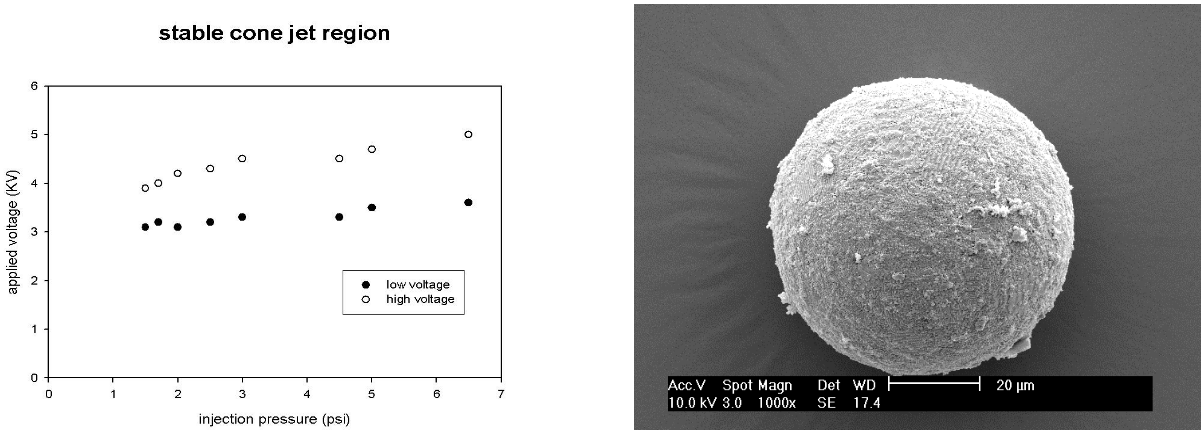

Fig 4. Stable cone-jet region of PS latex under d.c. electricfield. And their representative SEM image.