# Patterned Self-assembly of Fine Particles by the Combination of Dispenser and Positioning Stage

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**Abstract**

Drying-up suspension that contains fine particles, regular micro/nanostructures of the particles are self-assembled. This paper proposes a patterned self-assembly in which both of dispenser and stage control are used to generate the pattern without using mask. The spreading width of suspension changes with various factors. Thus, feedback control was tried in which the dispense rate and time are controlled to keep the width constant. As a demonstration, ϕ1μm silica particles were assembled over lines of 20μm width. The assembly was packed structure of monolayer.

## 1 Introduction

Dip coating with suspension that contains fine particles can produce self-assembly of the particles [1]. To obtain patterned assembly, substrate should be patterned in advance with lithography to make wettability pattern for example [2]. By integrating dispenser and stage control, mask-less self-assembly can be possible by supplying the suspension only on the required portion. This process has a merit of the consumption saving of suspension as well as scalability to large substrate. However, the viscosity of water-based suspension is low and precise control is difficult. This paper discusses a feed-back system to obtain precise assembly.

## 2 Setup and conditions

Figure 1 shows the setup for experiments. A dispenser was set over a 3-axis motion stage. A substrate was fixed on the motion stage of which position was controlled simultaneously with the dispenser by a PC. Dispensed suspension contained particles and they were self-assembled as the evaporation of solvent. The driving force of the assembly is the meniscus force between the particles. Thus, the solvent mainly used

was water because of large surface tension and easiness of handling. A microscope with camera was installed beside the nozzle to construct real-time feedback system.

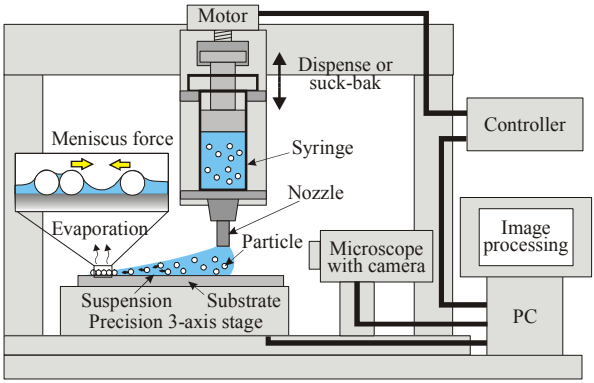



Figure 1: Experimental setup for self-assembly with dispenser system

Figure 2 shows schematic illustration of the suspension spreading over the substrate. The gap between dispenser nozzle and the substrate should be kept as narrow as possible to make the spreading width small. The contact angle at the backward of the motion is equal to the receding-angle determined by equilibrium of interfacial tensions. Modeling of this mechanism is difficult because the evaporation of the solvent may induce Marangoni convection which makes the mechanism complicated.

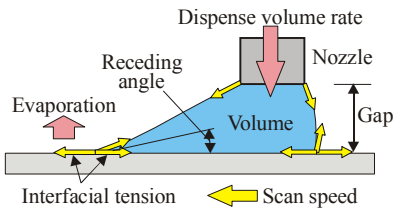



Figure 2: Schematic illustration of spreading on the substrate

Table 1 summarizes the experimental conditions. The dispenser nozzle diameter was 0.1 mm and the gap between the substrate was set between 0.1-0.6 mm analyzing the captured image. The suspension contains silica particles of ϕ1μm. The substrate was glass as hydrophilic material or polypropylene as hydrophobic material.

Table1: Experimental conditions

| | | | | | |
|---|---|---|---|---|---|
| Dispenser | Nozzle diameter | 100 μm | Suspension | Particle | $SiO_2$ (ϕ1μm), 1 vol% |
| | Dispense rate | Max. 0.7 μl/s | | Solvent | Pure water |
| | Gap | 0.1-0.6 mm | | Surfactant | Sodium dodecyl sulfate |
| Substrate | | Glass, Polypropylene | | | |

## 3 Results and discussion

### 3.1 Spreading of water droplet

Pure water was dispensed to investigate basic property of spreading on the substrate. The left side of Fig.3 shows the captured images. Depending on the wettability of substrate, the profile of droplet (2 μl) became different. It can be seen the droplet spread wide in case of hydrophilic substrate. The right side figure shows schematic illustration of captured image. The parameters including the width *W* was quantified by processing the image. The cycle time of the processing was shorter than 0.1 s, thus real-time control was possible.

Figure 4 shows the results of control on a glass substrate. Spreading width can be controlled with both of the dispense time and rate. Figure 4(a) shows the result of time control. The minimum width was about 1 mm. Figure 4(b) shows the result of dispense rate control. The minimum width was about 1 mm in this case.

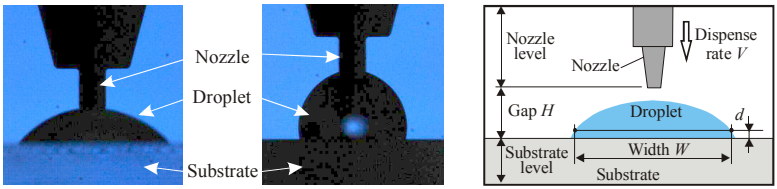
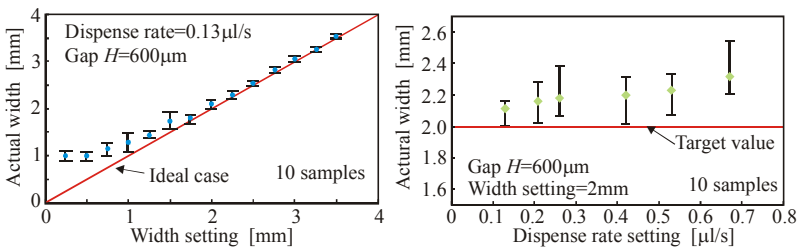



Figure 3: Droplet of water droplet on the substrate and scheme for image processing




(a) Control with dispense time (b) Control with dispense rate

Figure 4: Control of spreading width

### 3.2 Patterned self-assembly of particles

Figure 5 shows the results of patterned self-assembly of silica particles. The left side figure shows the dots pattern of 4 mm spacing on a polypropylene substrate. Intermittent pattern was successfully produced with constant diameter owing to the control. The assembly was multilayer because the substrate was hydrophobic and spreading area was limited. The right side figure shows the parallel pattern of 500 μm spacing on a silicon substrate. In this case, the dispense rate was kept constant while applying linear motion at constant speed. The assembly was monolayer because the substrate was hydrophilic and suspension spread widely. The width was about 20 μm. Accuracy of assembly should be improved with proper control as a future problem.

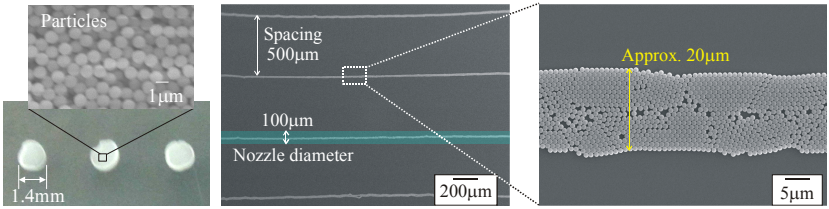



Figure 5: Patterned assembly of ϕ1μm silica particles (left: dots, right: lines)

## 4 Conclusions

Integrating dispenser and stage control, patterned self-assembly of particles without mask was demonstrated. The results are summarized as follows:

(1) The spreading width of water droplet was controlled down to 1 mm using ϕ0.1mm nozzle by applying feed-back control based on image processing.

(2) ϕ1μm silica particles were assembled in dots or along lines. Packed structures of single layer were obtained for lines of 20 μm width.

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**References:**

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[2] A. Kaneko et al., An application of dip-coating technique to fabrication of self-assembled microstructure on hydrophilic/hydrophobic patterned substrate, Proc. 6th euspen, 2006, pp. 288-291.