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NUMERICAL STUDY OF A PATTERNING PROCESS USING MICRODROPLET EJECTION

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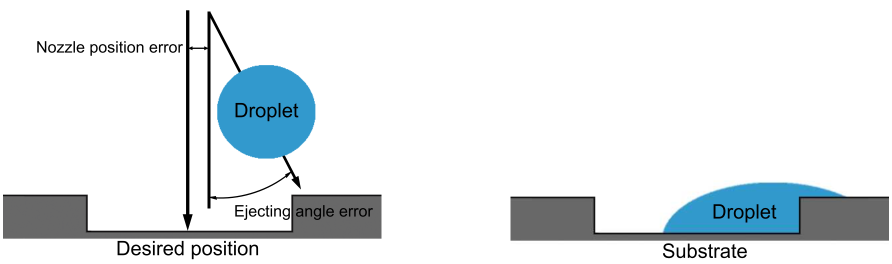
ABSTRACT

Inkjet printing technology has recently received increasing attention in various patterning processes such as required in manufacturing color filters of LCD(liquid crystal display), DNA micro array, organic TFT devices, light-emitting diodes, and micro-lens [1,2]. Compared with the popular lithography patterning, the inkjet patterning process, in which a microdroplet is ejected through a nozzle and deposited into the pre-patterned substrate, has significant advantages in manufacturing procedures and production cost. For high resolution patterning, it is very important to accurately place a droplet to the target position. However, the inkjet process possibly has some undesired patterning errors caused by the inaccuracy in nozzle position and ejecting angle, as shown in Figure 1. One of the efficient techniques to overcome the patterning error is to use the multiphase characteristics between the liquid-gas-solid phases. An example is to self-align a droplet on the combination of hydrophilic substrate and hydrophobic micro-structure by controlling the surface energy at the contact of three phases [3].

Despite a number of applications, the inkjet patterning process has not been properly analyzed because of the complexity of the process occurring in micro time and length scales and the liquid-air interface that evolves and breaks up, the flow fields influenced by the interfacial motion, and the immersed (or irregular-shaped) solid.



(a) (b)

Figure 1: Schemetic diagram of inkjet patterning process: (a) droplet placement error and (b) undesired doplet deposition.

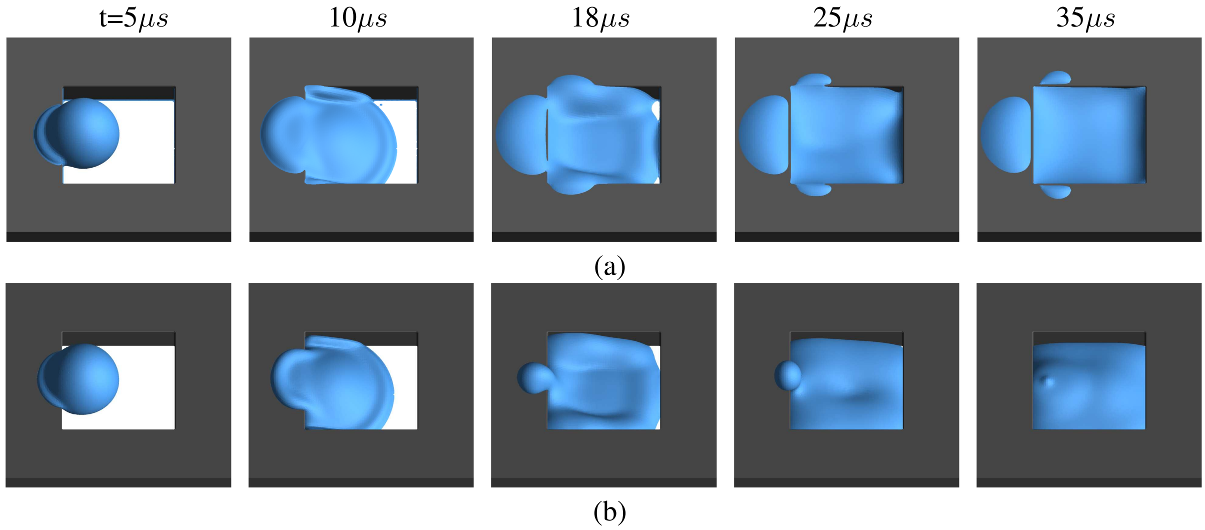


Figure 2: Effect of contact angle on droplet deposition pattern: (a) $\varphi_{structure} = 30^o$, $\varphi_{substrate} = 30^o$ and (b) $\varphi_{structure} = 30^o$, $\varphi_{substrate} = 120^o$.

In this study, a numerical method is presented for computation of micro droplet deposition on the pre-patterned micro-structure. The liquid-air interface is tracked by level set method improved by incorporating the ghost fluid approach based on a sharp-interface representation, which is effective for accurately enforcing the matching conditions at the liquid-gas interface and the no-slip condition at the fluid-solid interface. The method is further extended to treat the contact angle condition at an immersed solid surface which is described in detail in our previous work[4].

Figure 2 show the numerical results of droplet deposition pattern with droplet placement error. In the computation, the droplet has a diameter of $50\mu m$ and the hole has a width of $80\mu m$. The impact velocity of droplet is $8m/s$ and the substrate has a contact angle of 30^o. In the case of $\varphi_{structure} = 30^o$, the droplet spreads on both of the micro-structure and substrate and some portion of ink is left on micro-structure. In contrast, when the contact angle of micro-structure is increased to 120^o, most of droplet is observed to fill the hole.

In summary, a level-set method was developed for computing a patterning process by including the effects of contact angle and irregular solid surface. The numerical simulation of a patterning process using microdroplet ejection demonstrates that the multiphase characteristics between the liquid-gas-solid phases can be used to overcome the patterning error.

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