Numerical Simulation of Micro-Fluidic Flows of the Inkjet Printing Deposition Process for Microfabrication

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Abstract

Droplet impinging into a cavity at micro-scale is one of important fluidic issues for microfabrications, e.g. bio-chip applications and inkjet deposition processes in the PLED panel manufacturing. The droplets generally dispensing from an inkjet head, which contains an array of nozzles, have a volume in several picoliters, while each nozzle jets the droplets into cavities with micron-meter size located on substrates. Due to measurement difficulties at micro-scale, the numerical simulation could serve as an efficient and preliminary way to evaluate the micro-sized droplet impinging behavior into a cavity. The micro-fluidic flow is computed by solving the three-dimensional Navier-Stokes equations through a finite volume discretization. The droplet front is predicted by a volume-of-fluid approach, in which the surface tension is modeled as a function of the fluid concentration. This paper discusses the influence of fluid properties, such as surface tension and fluid viscosity, on micro-fluidic characteristics at different jetting speeds in the deposition process via the proposed numerical approach.

Keyword: *Micro-Fluidic Flow, Inkjet Printing, Deposition Process, Microfabrication*

1. Introduction

In order to obtain mechanical or electrical devices at micro-scale, microfabrication becomes one of the interested fields for recent researches. Several microfabrication processes, such as LIGA and inkjet printing, have been proposed and realized. PLED display panel is a good example of inkjet printing microfabrication, which uses the inkjet printing technology to generate thousand of micron-sized pixels. Because the inkjet deposition process reduces manufacturing costs and process steps when compared with the traditional etching and/or lithography, it seems to be the best candidate in manufacturing the next generation of electronics and color displays using PLED [1]. The state-of-art inkjet printing/deposition technology for mass production dispenses droplets from a piezoelectric inkjet head, which generally contains an array of nozzles, Fig.1. The commonly chosen non-dimensional numbers to describe such process are the Weber number (*We*), the Reynolds number (*Re*), the Ohnesorge number (*Oh*), and the Bond number (*Bo*), [2]. These four non-dimensional numbers characterize the ratio of magnitude among inertia force, surface tension, viscous force and the gravitational force. This paper discusses the influence of droplet initial velocity and fluid properties on micro-fluidic characteristics in the deposition process of microfabrication via a numerical approach.

2. Numerical Schemes

The numerical scheme is based on a finite volume discretization and a volume-of-fluid method. The continuity equation and the Navier-Stokes equation are solved using the finite volume discretization, while the volume-of-fluid method is employed to consider the transport phenomenon of fluid fraction c. All vectors quantities, e.g. position vector, velocity and moment of momentum, are expressed in Cartesian coordinates. Non-staggered variable arrangement is used to define dependent variables: all physical quantities are stored and computed at cell centres. Finally, the SIMPLE algorithm [3] is adopted to calculate the velocity and pressure coupling. Both fluids are treated as a single effective fluid, whose physical properties vary in space and are calculated according to the volume fraction of fluids in cell. The surface tension is calculated by a continuum surface force model. This model uses the gradient of c to define the normal vector at the interface pointing from gas to liquid.

3. Numerical Results

The schematic of droplet impinging into a cavity is shown in Fig.2, where the cavity depth is h, the droplet diameter D, the cavity width L and the centre height of droplet H. Because the interaction time is very small, the visco-elastic characteristics of polymer and the temperature effect on fluid properties are neglected in this study. Due to the symmetry reason, only one quarter of the cavity is considered. A three-dimensional Cartesian grid with about 20000 grid points is used to discretize the computational domain. Fig.3 and Fig4 describe the top-view and side-view of an impinging process. If the Weber number is smaller than 3.0, the fluid layer would be no longer exist.

4. Conclusion

The droplet impinging behaviors during the inkjet printing process for microfabrication have been conducted in the present study via a numerical approach. Some important critical non-dimensional parameters have been found. If the Weber number is smaller than the critical value, the fluid layer would no longer exist. If the Reynolds number switches from larger than the critical value to smaller than the critical value, the wall-collision time could reduce by 2 in the order of magnitude. However, the critical Weber number and the critical Reynolds number are a function of other non-dimensional parameters.

Acknowledgement
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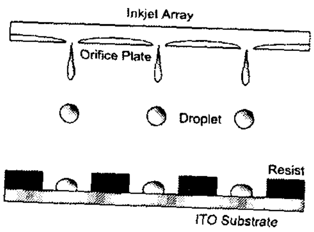
References

[1] http://www.litrex.com/
[2] A. Frohn and N. Roth, Dynamics of Droplets, Springer Verlag (2000).
[3] S.V. Pantankar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing (1980).

Fig.1



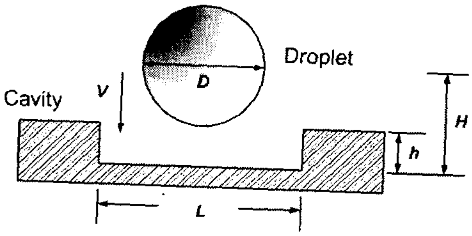


Fig.2

Fig.3

Fig.4

t^*	$V = 5.0$ m/s, $\mu = 0.005$ N·s/m^2			
	σ (N/m)			
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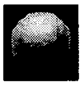
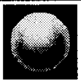
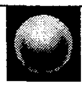
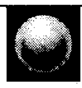
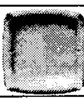
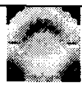
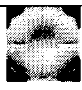
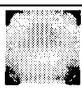
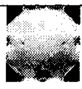
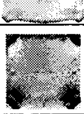
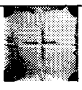
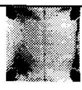
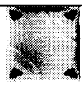
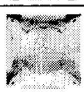
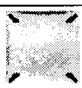
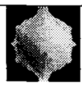
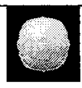
0.001				
0.005				
0.010				
0.050				
1.000				

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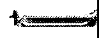
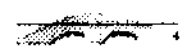
0.005				
0.010				
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