Development of a high-speed pattern-coating technology: "Air-Bubble Coating"

I-Chun Lin and An-Bang Wang*

Institute of Applied Mechanics, National Taiwan University,
No.1, Roosevelt Rd., Sec. IV, 106 Taipei, Taiwan, Republic of China
* abwang@mems.iam.ntu.edu.tw, +886-2-33665651

Presented at the 14th International Coating Science and Technology Symposium,
September 7-10, 2008, Marina del Rey, California[1]

I. Introduction

Patterning technology has become quite hot in recent years. Different ideas by the aid of pre-patterned masks have been developed and tested in the industry/research laboratory, for instance, photolithography[1], stamping[2], and electro-deposition[3] methods etc. Among these methods, masks are needed and costly. As the design is modified or changed, new masks have to be reproduced and thus increase the cost. Therefore, "maskless" patterning methods become the main key issues in the industry. One of the most popular candidates among them is the technology of "Ink-jet printing"[4], in which, some tens of micrometer-sized droplets are generated and millions of droplets are supposed to be precisely deposited on the specific locations of substrate to form the designed pattern. Principally, ink-jet printing has the advantage to easily change the design pattern and save the cost of material; however, there are still the problems of low production rate, high maintenance cost, and non-uniformity etc.

For uniform and rapid material depositing, wet coating technology is one of the most important methods. The wet coating technology includes many kinds of methods for different applications, such as die coating, slot coating, curtain coating, and roll coating etc. To directly produce a discontinuous pattern, an advanced discontinuous wet coating technique is required. In the literature, there are several kind of methods are reported [5][6]. Choinski and Mass[5] use slot coating with a mechanical valve to control the supplying fluid which cooperates with the substrate motion to generate discontinuous pattern. Harada et al.[6] utilized roll coating method by controlling the related position of rolls to feed liquid and cut of liquid film sequentially for liquid film pattering.

All the present discontinuous coating methods utilized mechatronic action for liquid film cutting. However, with the mechatronic methods a very complex equipment and process are required to produce micro-size and highly precision pattern. In this paper, a novel discontinuous coating method "Air-Bubble Coating" is brought up. This method can be considered as an advanced-die-coating method, which combine the well-know die coating technology with the discontinuous coating source to generate the micro-patches, the schematic diagram is shown in **Figure 1(a)**. Micro-two-phase flow is utilized to be the upstream discontinuous coating source, in which air bubbles are installed to separate the coating material as a release valve, precise timer and segment divider. An uniform patch films can be directly, speedily, repeatedly produced.

---

[1] Unpublished. ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

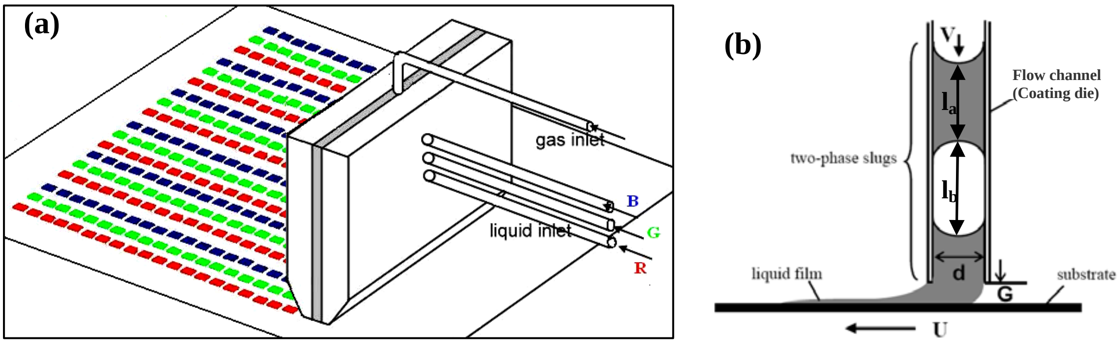

Figure 1 Schematic diagram of **(a)**Air-Bubble coating for color filter producing, (b)simplified model of Air-Bubble coating

II. Equipment Setup

Air-Bubble Coating combines two actions, micro-two-phase-flow supply and substrate motion, to generate micro patterns. **Figure 2(b)** shows the schematic diagram of simplified setup of air-bubble coating. Therefore, the whole coating instrument can be divided into two parts, one is micro two-phase flow supplier and one is motion stage to precise control the substrate moving velocity. And the micro two-phase flow supplier are fixed perpendicularly to the moving substrate keeping a constant distance (G), where the gap size is suggested with the same order as tube(or channel) diameter(d). The micro two-phase slugs are driven with the flow velocity V, which is counted by flow rate(Q) divided by the channel cross section(A). And the moving substrate which is commercial transparency PET film moves with a constant speed(U).

The micro-two-phase slugs are loaded into a glass capillary tube. The detail of two-phase slugs loading has been reported in the previews work[7], which product is shown in **Figure 2**. Several pairs of two-phase slugs contain a wettable liquid segment and a non-wettable air bubble.

Figure 2 Two-phase slugs loaded capillary tube: the blue parts are dyeing glycerol/water solution and the other non-wetting one are air bubbles

III. Coating Process of Air-Bubble Coating

The capillary tube is a simplified model to imitate one of flow channels of the coating die, which is for convenience of coating detail observation. For coating process observation a high speed camera(Photron, FastCAM 10K) is utilized, the visualization results are shown in **Figure 3**. The upper cylinder is the coating channel which contains with two phase slugs and the lower one is its reflex image by coating substrate. The substrate moves from right hand side toward left and keep a constant gap(G) with the coating channel outlet.

The coating operation status can be separated into two states: liquid-film-deposit state and air-disperse state. As liquid front edge touch the coating substrate begins the liquid-film-deposit state(Photo(a)), and then the liquid bridge bended toward the moving direction(Photo (b)). The liquid film coats on the substrate uniformly Photo(c)-(e). After the liquid-air interface flowing out the channel, the air bubble which surrounded by very thin liquid film moves out off the channel gradually and touch the coating substrate, Photo(f). When the surrounded liquid film can not bear the bended stress anymore, the liquid film is apart from the coating channel Photo(g), then a liquid patch film forms, after that the process goes into air-disperse state. Within the air-disperse state the contained air moves out off the channel and disperse into atmosphere(Photo(h)) and “nothing” coats onto the moving substrate till the following liquid slug arriving the channel outlet, the next cycle begins. Repeating the cycle, a serial micro pattern can be produced.

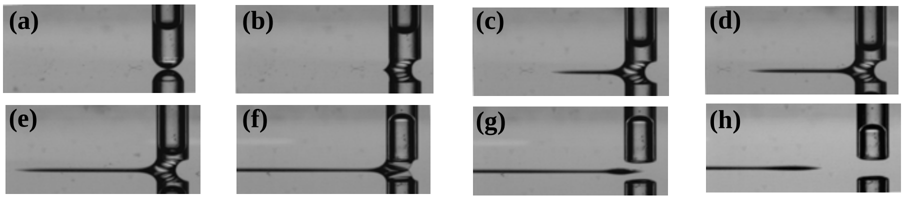

Figure 3 Flow visualization of air-bubble coating with capillary tube

In last section, the operation status of Air-Bubble coating has been introduced. However, to produce a well-coated film is not a casual work. The same as the traditional wet coating technology, to produce a well-coated liquid patch, several important operation parameters should be considered such as gap size(G), the two-phase mean flow velocity(*V*) and the substrate moving velocity (*U*). Successful coating requires that the operating parameters, the two-phase mean flow velocity(*V*) and the substrate moving velocity (*U*) etc., lie within the applicable operation region. In the applicable operation region, which is named as Coating Window, stable well-coated films can be produced. Outside the window is the unstable region.

In this paper, we imitated the traditional coating technique to find out the coating window of air-bubble coating, **Figure 4**. The well-coated film of air-bubble coating has the same definition as traditional die coating that a film should be with uniform width and thickness. Otherwise, for air bubble coating an additional criterion is required that each patch of film should be separated clearly. The coating window, whose region is bounded by the red and blue curves and the black diamonds are the testing points. Out off the coating window exit several kinds of failure films: **(i)**non-separated film, **(ii)**pulled film with shrunk tail and **(iii)**fracture film.

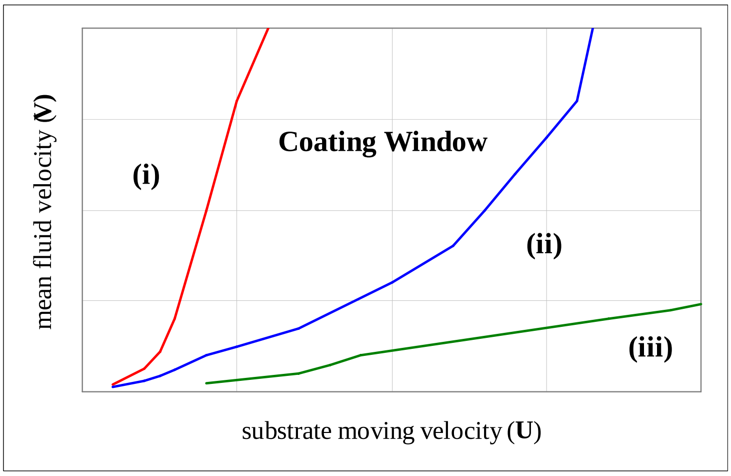

Figure 4 Coating Window of air-bubble coating of simplified model

The details of each coating defeats, non-separated film, pulled film and fracture film will be introduced in presentation. The color filter coating result will be demonstrated.

IV. Acknowledgements

The financial support from National Science Council, Taiwan under contract numbers NSC 96-2221-E-002-200-, 95-2221-E-002-341-MY3, 95-EC-17-A-05-S1-017, 96-WFA0100067 and Chi Mei Optoelectronics (CMO) is gratefully acknowledged.

V. Reference

[1] NS Kawasaki et al. Color filter having different primary color pigment densities. US patent 4,786,148(1988)

[2] A Kumar and G Whitesides. Features of gold having micrometer to centimeter diameters can be formed through a combination of stamping with a elastomeric stamp and an alkanethiol "ink" followed by chemical etching. Appl. Phys. Lett. **63(14)**, 2002-2004, (1993)

[3] M Suginoya et al. Method for manufacturing a multicolor filter and a multicolor display device. US patent 4,522,691.(1985)

[4] HS Koo et al., Physical chromaticity of colorant resist of color filter prepared by inkjet printing technology. Appl. Phys. Lett. **88**, 111908, (2006)

[5] EJ Choinski and W Mass. Method and apparatus for patch coating printed circuit boards. US patent 4,938,994(1990)

[6] Y Harada et al. Process an apparatus for interment coating of a sheet without wrinkling thereof. US patent. 5,582,868(1996)

[7] IC Lin et al. Generation of micro-two-phase-flow for "Air-Bubble Coating". International Conference of Multiphase Flow. Leipzig. Germany.(2007)