Design Rule for Integrated Ink-Jet Fabrication Platform

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Abstract

*This article introduced the development of DTC/ITRI in ink-jet printing of display and printed circuit board and its platform architecture. Based on the ink-jet process need, the DTC L series are equipped twelve piezo heads and dual curing system, including UV curing and thermal curing, to ready for mass production of ink-jet printing fabrication. A real-time task console arbitrates the delivery of panel, monitors the control parameters floating, the memory management, the printing procedure, record of environmental conditions, and communication. System accuracy can reach within ±10 um at size of 600mm*700mm panel, and printing speed is up to 20 in /sec by adapting the dividing frequency technology (DTF). Maximum tact time is 20 sec at 400dpi*400dpi and 45 sec at 800dpi*800dpi for full panel printing region. Optical alignment and image compensation for original image deterioration was realized by tunable dual auto-focus CCD, at optical resolution of ± 1 um. Major functionalities for yield improvement like waveform modulation to address each nozzle driving and satellite drop, image trimming to compensate substrate surface property, image filtering to control the thickness of dispensing layer, complex service to clean head quality, multi-function loading table to hold a panel down during printing operation, condition of print-head strobe to set up printing nozzle database and lighting control to cure layer with high uniformity were also introduced. This article disclosed a detail design rule for consideration of ink-jet fabrication, and realized it in PCB and display application.*

Introduction

DTC/ITRI has been developed in the Ink-Jet Printing Technology on Manufacturing Color Filter for Liquid Crystal Display since 2001. This paper disclosed a completed system ready for UV curable material like legend on printed circuit board, but not limited only on certain purpose only, Ink-jet printing has the innate characteristics of saving material and directly patterning [1] [2]. Cheng et al. [3-5] shown the feasibility of ink-jet fabrication for color filter; which can simplify procedure and avoid high equipment expense. The specialty of ink-jet printing fabrication is the yield rate will be improved as size increases. Besides, cutting expense and simplified procedure make this technology more efficient and competitive for the PCB manufacturer... Now the PCB manufacturers faces the revolution and ready to adopt this new technology into traditional process with digitalization.

This article disclosed an ink-jet printing system that can produce versatile fine patterns with special curing process treatment, an image filtering and trimming scheme, a waveform modulation method, the multi-heads printing arbitration and the detail design rules for real fabrication.

Rule A: Printing Platform Layout

The platform can be classified into four main group: a four-axis X-Y-Z-θ platform , three printing head modules in total of twelve heads, an IR & UV hybrid curing system, a optical system used for alignment, and a maintenance system to help jetting health control. Figure1 shows a schematic view of this apparatus. In this architecture, it is expendable up to the printing size of over 1100mm*1300mm if it is needed for display application. Where the three printing head modules include 12 print-heads are mounted on the gantry frame supported on a granite base (AA Grade) with four vibration isolators to absorb the vibration. Moreover, two area CCDs read the alignment mark positions to align the position offset when loading substrate, and these marks are formed on the substrate in advance and can easy change by operator. A real time PC-based controller managed overall operation of the manufacturing process. The dimension of platform is about 2300mm (W)* 3000mm (L) * 1600mm (H). As for the printing speed, the maximum stage motion velocity is 25 in /s, and with the special divided frequency technology (DTF), the printing speed can reach up to 20 in/s, make the tack time of 20 sec at 400dpi*400dpi and 45 sec at 800dpi*800dpi resolution, respectively.

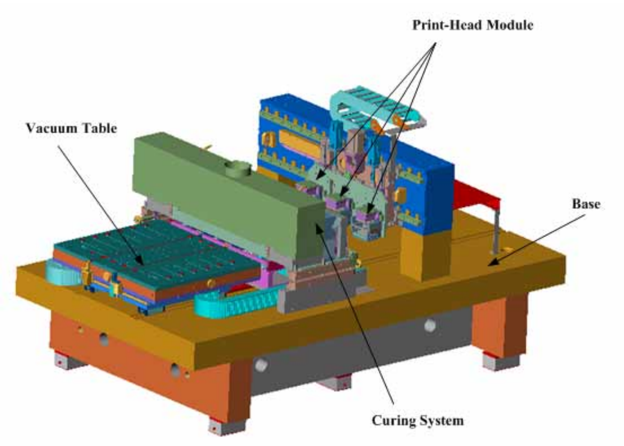


Figure1. Printing platform layout of DTC L series

Table Design

A multi-function loading table has four functionalities: a vacuum table with powered by air pump to suck the substrate in fix position and flat the surface, an adjustment mechanism to fit the substrate dimension, load and unloading pin help operator easy to release substrate, and finally, the clamp provided a mechanical alignment and a down force on the substrate surface, to correct the bending of substrate. As Figure2 indicates, the vacuum drove by vacuum pump to generate negative pressure during printing process and sucked the substrate to flat. After printing operation, the unloading will shore up the substrate, at the same time printing platform connects loading/unloading system to make automation.

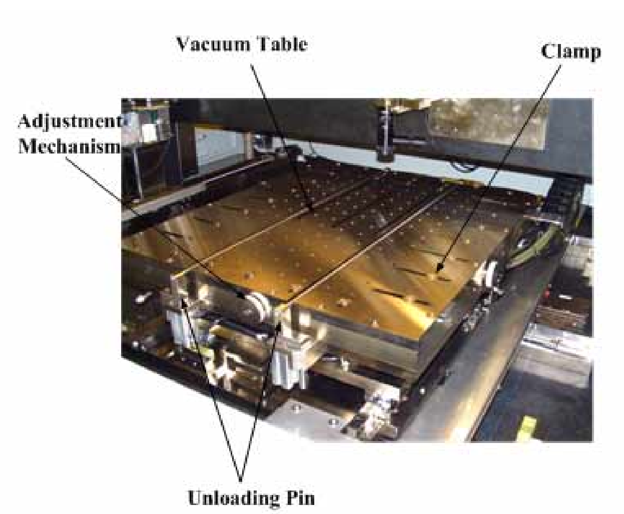


Figure2. Multi-function loading table

In order to keep printing platform in well working and retain the fine printing quality, the multi-purpose maintenance station was considered. Figure3 shown a carry module was fixed on the vacuum table, moving with the table at the same time. The capping is a traditional service function developed by office printer, it was used here to avoid light scattering into print head and kept a moisture environment to free of ink drying. For high dense ink, the wiper wipes off accumulation ink on nozzle plate... And if it is necessary, the absorber module, made of some porous materials can carry out the contaminated ink in printing process. A cover plate sliding to control the service on and service off, to avoid the light scattering from UV light source.

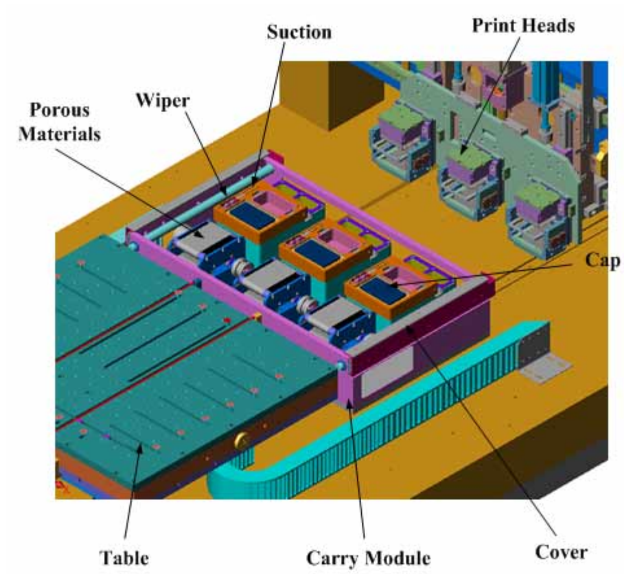


Figure3. Maintenance system

Multi-Print Heads Design

In our system support three printing modules, each module carry four heads, as showed in Figure4, in total of twelve piezo heads were assembled. The difficulty is the heat uniform distribution between heads, to keep the same operation at ink temperature and less variation caused by head temperature difference. For example, the UV curable legend ink, will be flowing into channel only above 60°C, its typically operation is at 70°C -80°C. It means while one heat this ink to 80 °C at ink chamber, must keep its heat dissipation to avoid the temperature lower than 65°C, and the head temperature variation must be within ±3°C in our experience to make sure the head-to-head quality problem. Figure5 shows the heat distribution of the print head module, when the main heater was operated at 80°C. In our system, a special three heating stages from ink chamber to print head is designed to avoid head dissipation.

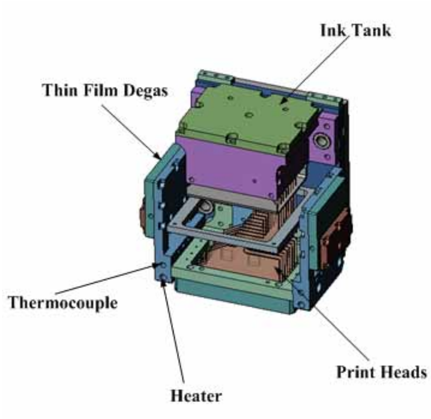


Figure4. multi-print heads module

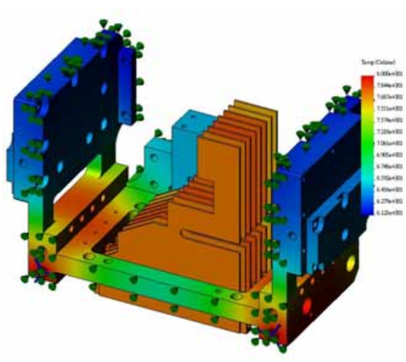


Figure5. Heat distribution of the print heads module

Rule B: Ink Curing Design

Typically, the ink drop landed on substrate needs some special process, by thermal cure or UV cure, to help the ink drop drying. However, the physics will cause shrinkage, stress release, solvent evaporation, or flow wetting, those kinds of physics induce the quality deterioration present. Therefore, in a design of view, we need elaborate design its key factor follow the process requirement. To observe first, the ring edge behavior and the trace of printing.

Ring Edge Behavior

Many studies have been performed on the evaporation of a drop of liquid on a substrate [6-7], and discuss on the behavior of particles accumulate at the contact line and form ordered arrays. Some groups have focused on how particles are distributed after the drying process [8-9]. Adachi et al. [16] observed that circular stripe patterns, i.e. rings, form inside the dried drops, and further noticed that the three phase (water, air, glass) contact line exhibited stick-slip motion as the water evaporated. It is important to note that motion of the contact line really refers to the disappearance of water due to evaporation and not to the lateral physical movement of the particles at the contact line. Shmuylovich[19] studied more detailed features of multi-rings behavior for latex. As shown in Figure6.

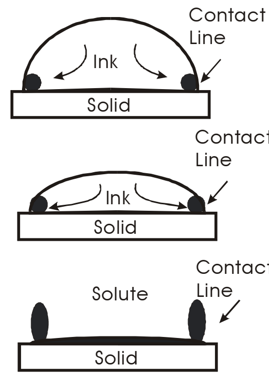


Figure6. Ring edge forming process.

Printing Trace

For some high viscosity ink, or low rheologic ink, the overlap between each swath printing will not be easy to merge together, and shown a non-flatting profile as in Figure7. To solve this problem, the designer can adopt external physical force or baking to ease the ink property before UV curing. It is a critical window for the designer needs to be carefully operation and will be disclosed below.

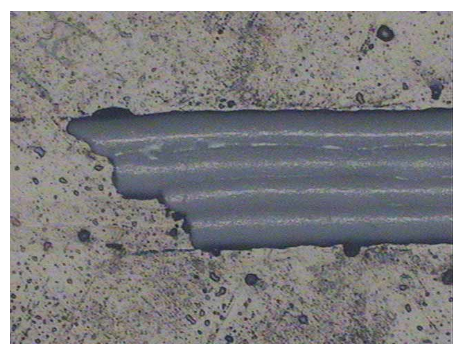


Figure7. printing trace caused non-flatting profile.

Rule C: Static Electricity & Pre-Heating

After ink-jet printing of this UV curable ink, before the substrate return to the unload position, in this system, an IR (Infrared Radio) provides heating power to help ink drop in flat, and then pass the UV (ultraviolet) curing stage. Our study found the pre-heating and static electricity remove will be helpful to get excellent layer profile. But it should notice that over power range of IR will rise high temperature on ink drops and cause the crack in drying layer. The static electricity device is an ion shower, to neutralize the electronic charges and support the cooling of IR & UV device at the same time, to avoid the high heating on substrate. The Figure8 showed this procedure of IR pre-heating, static electricity remove, and UV curing on deposited ink drops to drying.

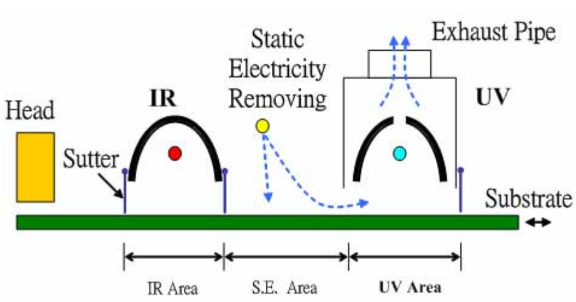
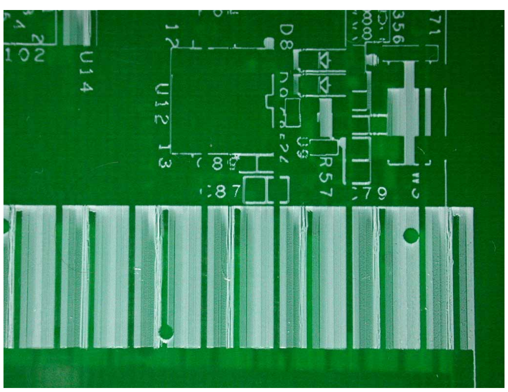
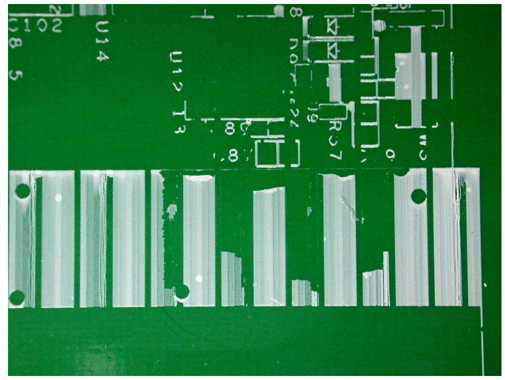


Figure8. The curing system and its operation procedure

As some examples to observe the quality, (a) full cure, fixed at 120W/cm UV light, working distance is about 28cm, time of exposure is 1 sec, in this case, the adhesive test by tape presented excellent attached, as in Fig.8. (b) Pre-cure, fixed at 120W/cm UV light, working distance is about 28cm, time of exposure is 0.5 sec, in this case, the adhesive test by tape presented portion peel off, as in Figure9.



(a) Full cure



(b) Pre-cure

Figure9. Curing example

Rule D: How to Design Electronic Controller

It is noteworthy that DTC L series IJP platform consisted of PC console、firing module and motion control. Figure10. is a sketch of the hardware protocol of printing module. The PC communicated with main board by USB interface to transfer printing data. The firmware control CPU to receive printing data , then setting FPGA (Firing Module) relative parameters to drive head printing in certain pattern. Simultaneously, the firmware sets the printing waveform to WGS/SX-TDC to modulate each nozzle to drive in different waveform, the so-called of addressable waveform. It is needed while the nozzle-to-nozzle variation is care. In our system design, the operator can easy setting each nozzle at different waveform and voltage threshold to tuning the variation between nozzles, and get more good quality desired.

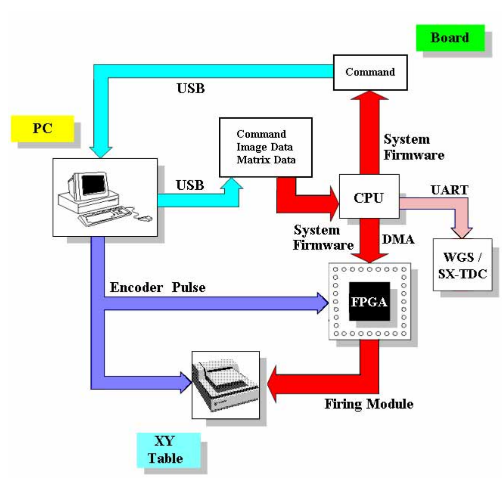


Figure10. printing system

Rule E: Software Functionality Required

For mass production, the software design of DTC L series IJP platform integrated image terming and filtering, strobe system, waveform control, drop on demand, service function, environment control, and printing project.

An ink-jet printing system for forming circuit patterns onto the surface of a printed circuit board (PCB) needs a different input data from classic PCB processes. The standard protocol of PCB is Gerber RS274X, which is a description language, not raster data for ink-jet printing. In our system pre-calculated printing data and make project file to save the printing data. The program supplies input, output, delete, and view data functions. As shown in Figure11.

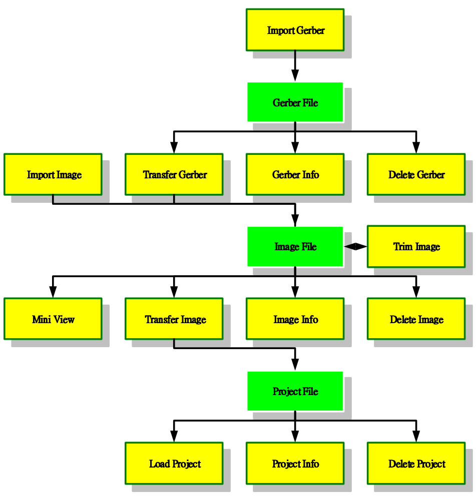


Figure11. the project of printing data flow chart

Figure12. DTC L series IJP platform

Conclusion

In our printing system disclosed design rule: printing platform layout, ink curing design, static electricity & pre-heating, electronic controller, and software function. It Industrial Ink-jet Printing is becoming a viable process in PCB manufacture. The DTC L series IJP platform equipped twelve piezo heads and dual curing system, including UV curing and thermal curing, to ready for mass production of ink-jet printing fabrication.

- ■Productivity by Multi-print heads module.
- ■Good adhesion by curing system.
- ■High quality by Addressable Waveform Setting.

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Biography

***Chih-Jian Lin** received his Master degree in Mechanical Engineering from National Taiwan University of Science and Technology in 2001. He is now a system integration engineer in the Display Process Integration Technology Division, Display Technology Center of Industrial Technology Research Institute in Taiwan. His work has primarily focused on the Opto-mehantronic integration and industrial ink-jet printing processes development, as color filter, Polymer Light Emitting Device (PLED), micro-lenses, organic TFT by ink-jet printing, etc.*

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