2021 Inkjet Technology Trend for Display

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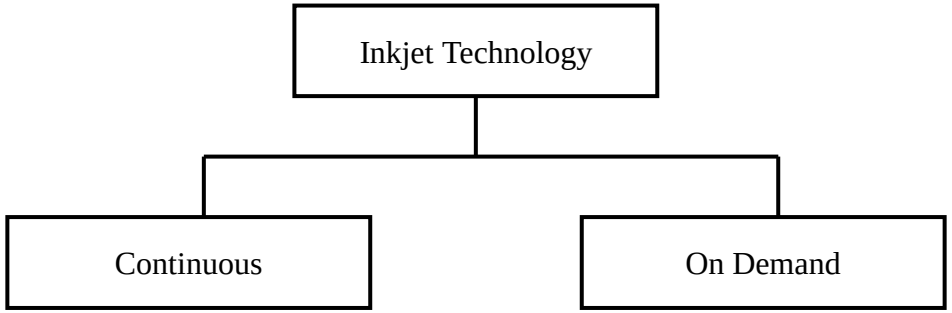
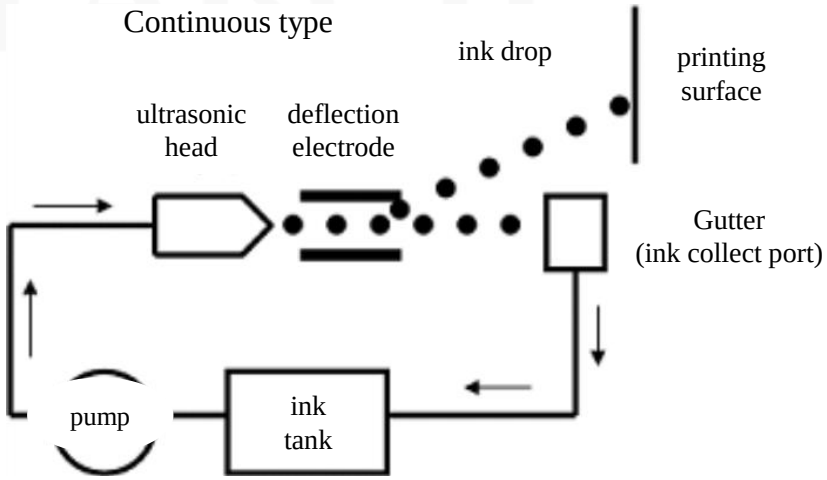
Contents

1.2 Inkjet Printing Technology Classification

- **Continuous type**
  - Inkjet Printing, which is typical of non-contact printing, is roughly divided into continuous type and on demand type.
  - In the continuous type, ink is always ejected from the head as shown in the figure below, and a signal is applied to the deflection electrode at the printing timing to eject the ink toward the printing surface. At other timings, the ink is ejected toward an ink collection port called a gutter and collected in an ink tank.
  - The good points of the continuous type are that the ink is constantly ejected, so even quick-drying ink does not cause defects due to clogging of the nozzle, and the ink can be extruded with high pressure, so highly viscous ink can also be used. However, since it is difficult to make a multi-nozzle and the device becomes large, this method is only used for industrial markers.





Ref. Wikipedia

1.4 Piezo Inkjet Printer

- **Ink ejection control of piezo inkjet printer**

Uniformization of ink ejection amount

- In the piezo method Inkjet head, the discharge amount varies slightly for each nozzle. There are the following methods to correct this.

1) DPN (Drive Per Nozzle)

Each nozzle is driven individually, and a drive waveform that makes the discharge amount constant is applied to each nozzle. (Fig. 1) This method is widely used in Konica Minolta heads.

2) Nozzle Mixing

If one pixel needs to eject n drops, instead of ejecting n drops from one nozzle, eject one drop from n nozzles. (Fig. 2) This method is introduced in Kateeva machine.

Fig. 1

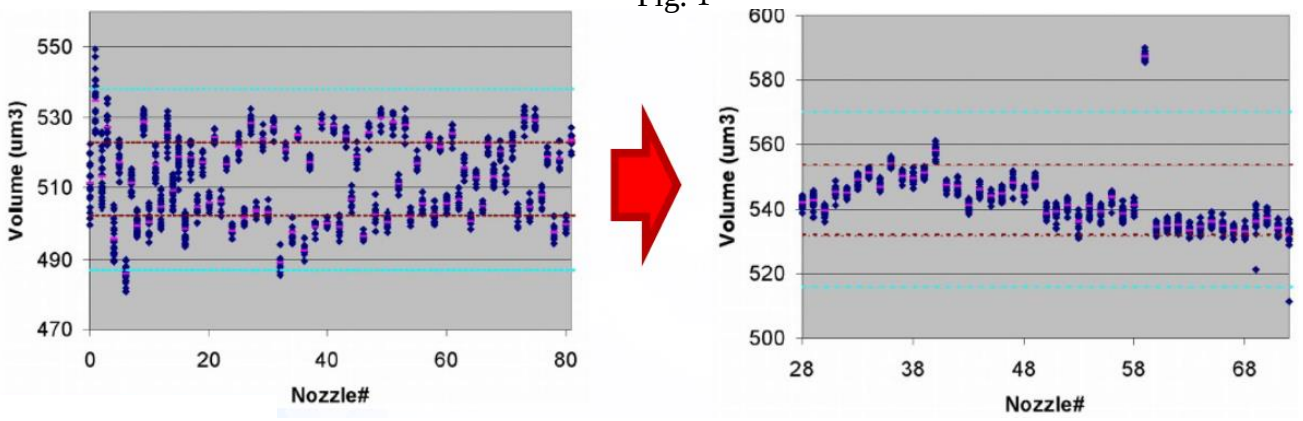
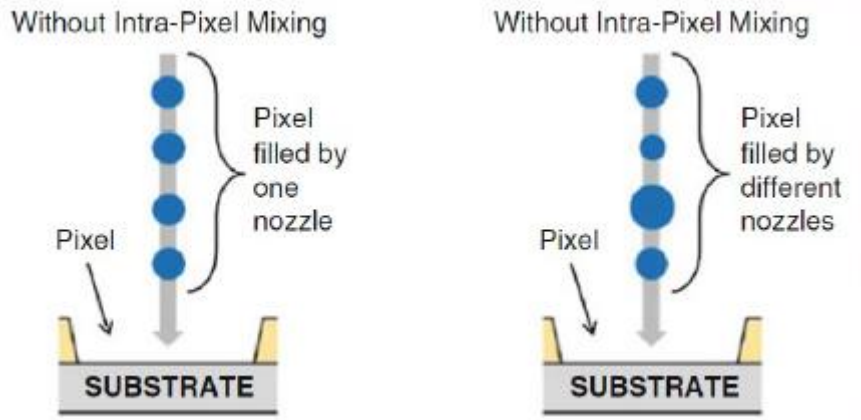


Fig. 2

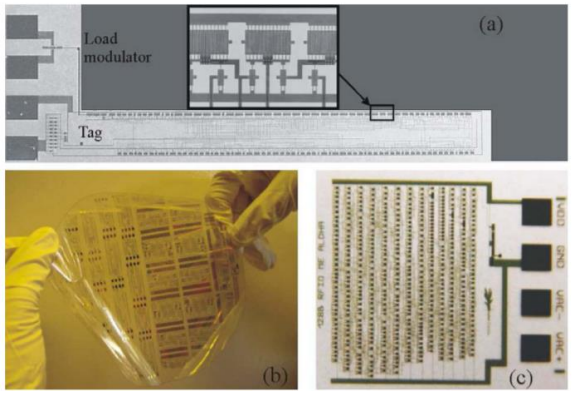


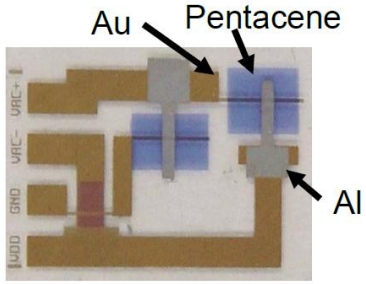
2. Printed Electronics

2.2 Application Example of Printed Electronics

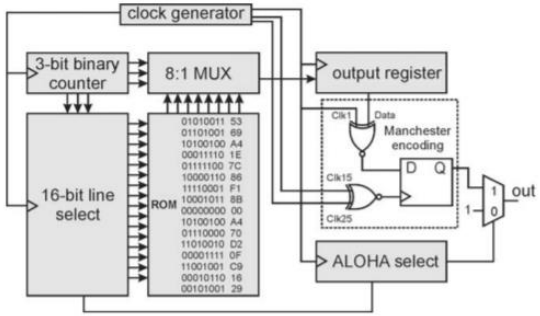
- Flexible electronics, which is based on the printing process, reached its heyday around 2010, and various circuits and devices such as the RFID tag circuits, film-type memories, and film-type optical sensors were developed.
- After that, FHE (Flexible Hybrid Electronics), which uses Si IC to produce only the parts that are more suitable for printing, became the mainstream, instead of producing everything by printing.

128 bit Organic RFID Transponder chip



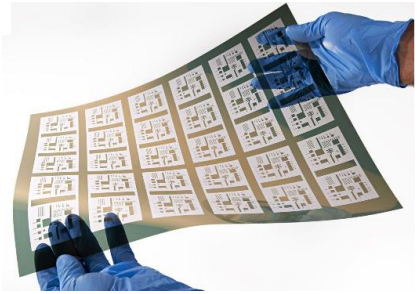


Holst Center, ISSCC 2009



13.56MHz RFID tag

Plastic memory using ferroelectric polymer



Organic photo sensor

2.5 Printed Electronics Application Devices

- TFT
  - In 2015, JAPERA (Japan Advanced Printed Electronics Research Association) developed a TFT array manufactured by the entire printing process, using inkjet printing as part of the process. *
  - The structure of the TFT is the bottom gate/bottom contact structure shown in Fig. 1, and the organic semiconductor layer is formed by inkjet. The gate and source drain electrodes were formed by offset printing, and the gate insulator was formed by slit die coating. The formed TFT array is shown in FIG. The substrate film is 30 μm thick, 300 x 400 mm, and has a density of 85 ppi.
  - The TFT characteristics are shown in FIG. 3. The average mobility was 0.3 $cm^2/V \cdot s$, the average on-current was 5 μA, and the in-plane variation was σ <10%.

Fig. 1

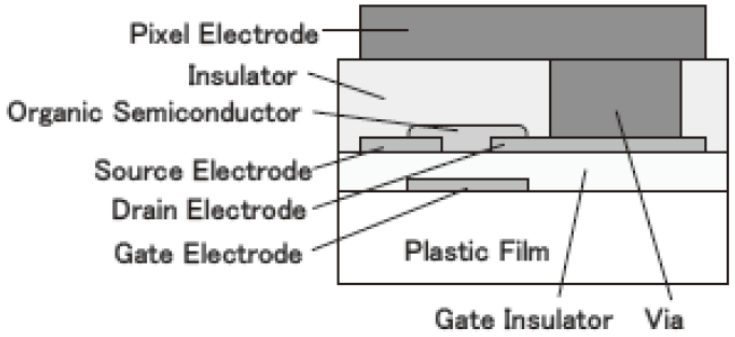


Fig. 2

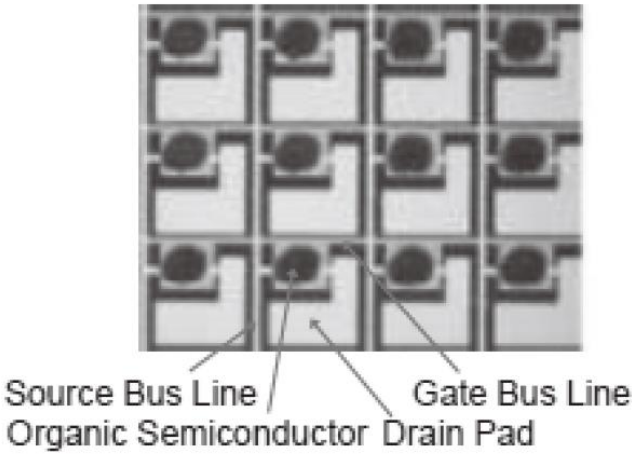
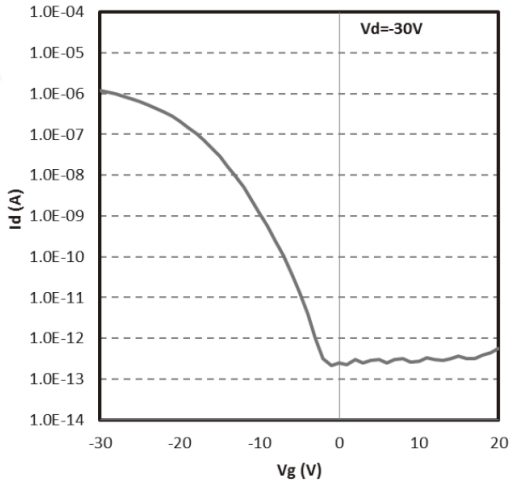


Fig. 3

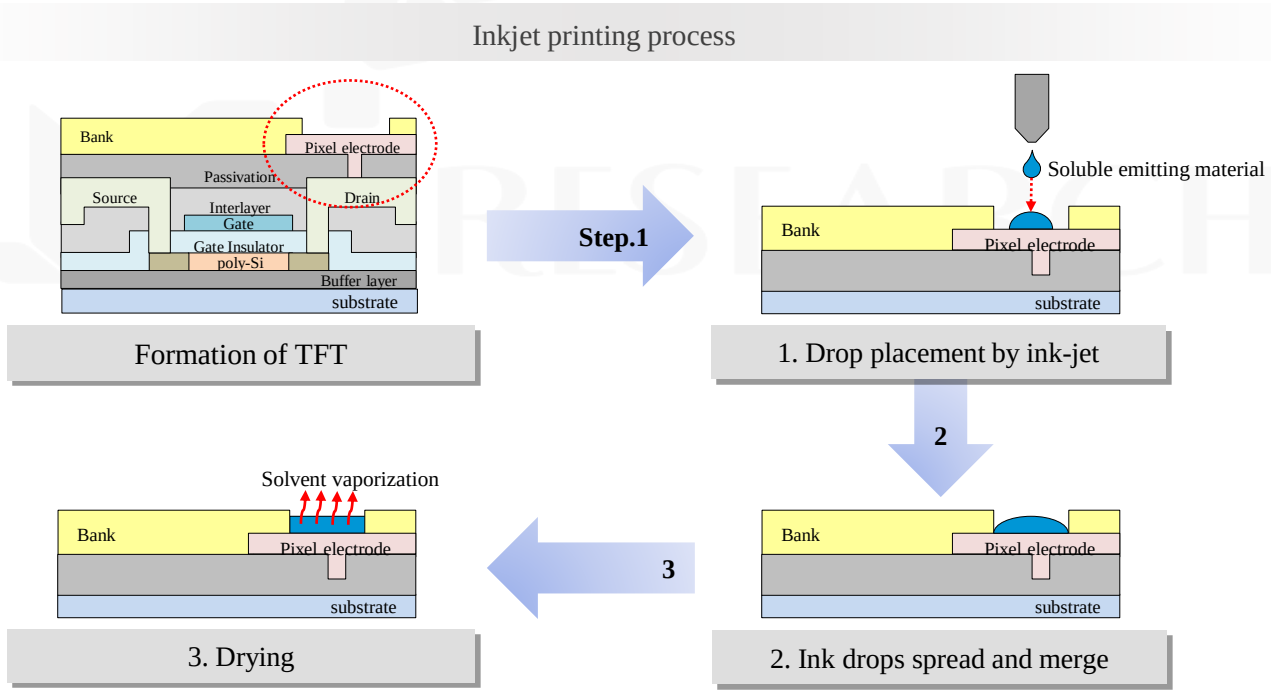


* Shinichi Nishi, Journal of the Japanese Society of Photography, 2015, Vol. 78, No. 2, 66-69

3. Solution Process OLED

3.1 Solution process OLED introduction

- Solution process OLED definition
  - The figure below shows the process flow of active matrix OLED by solution process. After completing the TFT process up to the pixel electrodes, a bank is formed by PDL (Pixel Defining Layer), and the emitting material is printed by inkjet in the bank. After that, it dries to form a light emitting layer. Since the OLED device has a structure in which a plurality of organic layers such as a carrier injection layer / transport layer and a light emitting layer are stacked, the inkjet & drying process is performed multiple times.

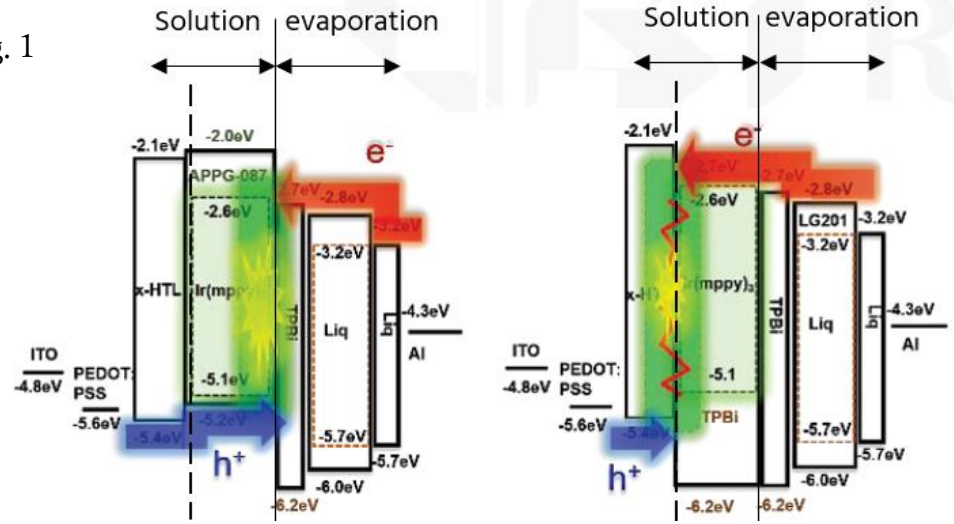


Source: UBI Research DB

3.4 Solution Process OLED Process & Device Development

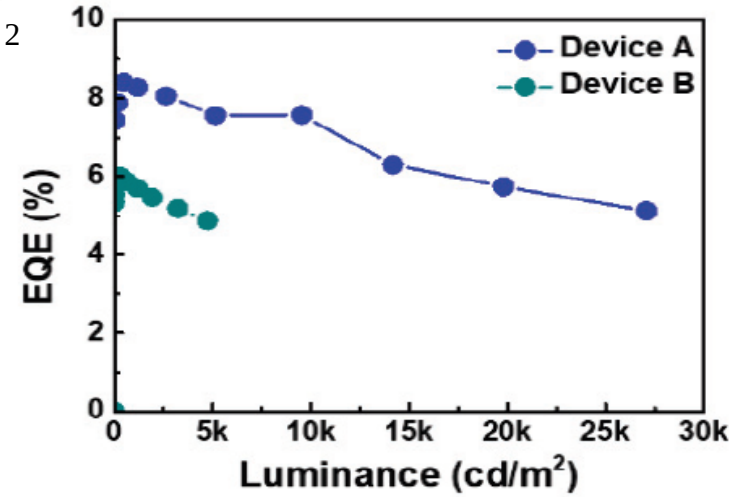
- Interlayer mixing
  - Kyung Hee Univ. Investigated the relationship between the position of the interface where interlayer mixing occurs and the position of the carrier recombination region and reported it at IDW2020. *
  - They used HTL, HBL, ETL, and EIL as a common layer, and device A with only the EML host as the electron-transporting TPBi and device B with the hole-transporting APPG087 were prepared. Here, HTL and EML are formed by solution process, and HBL, ETL, and cathode are formed by vacuum deposition, so Interlayer mixing occurs at the interface between HTL and EML as shown in Fig. 1.
  - Figure 2 compares EQEs for these two devices. Device A shows a higher EQE than device B. As shown in FIG. 1, the position of the recombination region of electrons and holes shifts depending on the host. In the case of device B, it is considered that the characteristics deteriorate because the recombination area is exactly at the position of interlayer mixing. That is, it is shown that even if interfacial mixing occurs, characteristic deterioration can be prevented by appropriately designing the position of the recombination region.

Fig. 1



wet interface wet interface

Fig. 2



* The Na Le et. al. IDW2020 Digest OLED 1-4 p.371

3.4 Solution Process OLED Process & Device Development

- Resolution
  - Currently, the highest resolution product of the solution process OLED manufactured by the inkjet process is JOLED's 204 ppi. Then Juhua reported in SID 2020 an examination of what would happen if this were 403 ppi.
  - The pixel dimensions for an RGB stripe array at 403ppi shown in Figure 1. That is, the minor axis width of each sub-pixel is 13 μm. On the other hand, the relationship between the volume and diameter of the droplet is as shown in Fig. 2. For example, when the droplet is 1 pL, the droplet diameter is 12 μm. Therefore, when this droplet is superimposed on the cross section in the minor axis direction of the sub-pixel, it becomes as shown in FIG.3. If the landing accuracy of this droplet is ± 10 μm, it is impossible to accurately eject the droplet into the sub-pixel.
  - Juhua newly designed a pixel pattern to solve this problem and used a 4.92inch 403 ppi high-definition panel under the printing conditions of droplet volume: 5 to 8 pl, bank width: 15 μm, and landing accuracy: ± 15 μm. The prototype was successful, but the pixel pattern has not been announced.

Fig. 1

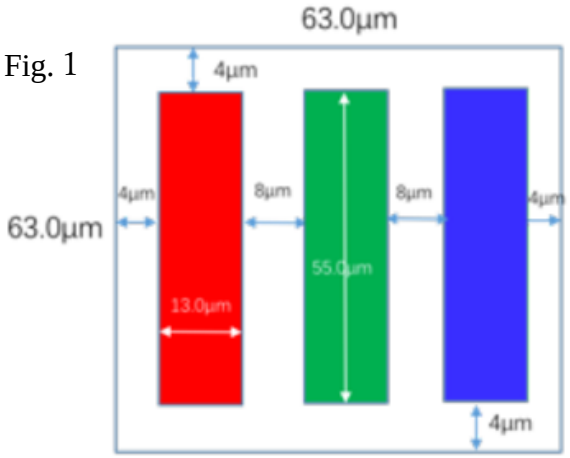


Fig. 2

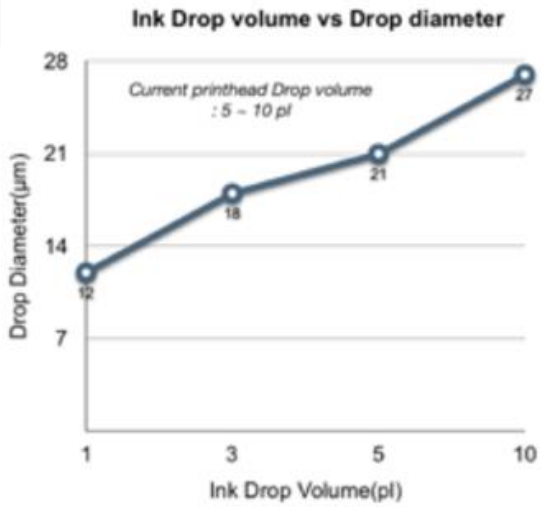
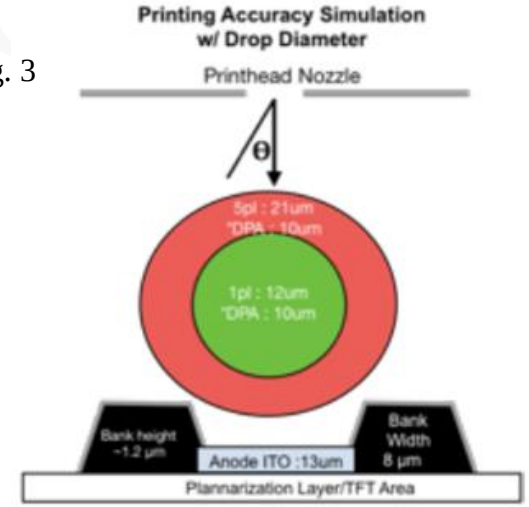


Fig. 3



4.3 Color Conversion Quantum Dot

- QD ink for inkjet
  - Ink jet printing ink for color conversion QD was jointly developed by DIC and Nanosys and reported at IDW2017.
  - The intended device is an LCD that has his backlight light source from blue and has a QD instead of a CF. This will increase the light utilization efficiency of the backlight and reduce power consumption. This method is a technology that can be directly applied to QD OLEDs and Micro LEDs.
  - QD has a high concentration (15 to 50%) to have sufficient color conversion characteristics, and 5 to 20% of TiO2 is mixed to further promote color conversion by scattering. Post-coating cures were tested for both thermosetting and UV curing. The inkjet head is from Dimatix.
  - Green and red QDs were printed with inkjet in a black matrix bank (height 2 μm) as shown in Fig. 1, and the blue sub-pixel was hollow. The resolution is 42 ppi. After printing and curing the green and red QDs, a translucent yellow film was formed on the entire surface to block the blue light transmitted through the QD layer.
  - Fig. 2 and Fig. 3 show this QD plate overlaid on the blue backlight.

Fig. 1

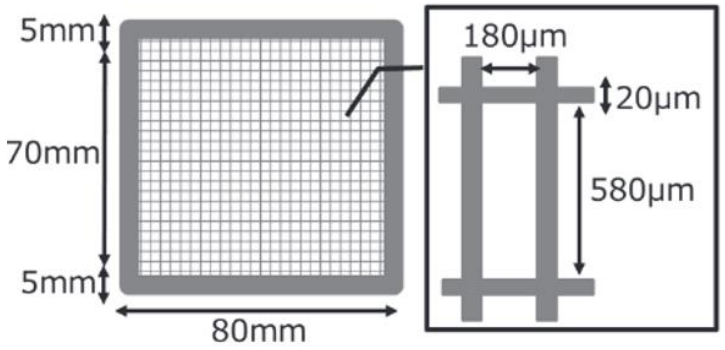


Fig. 2

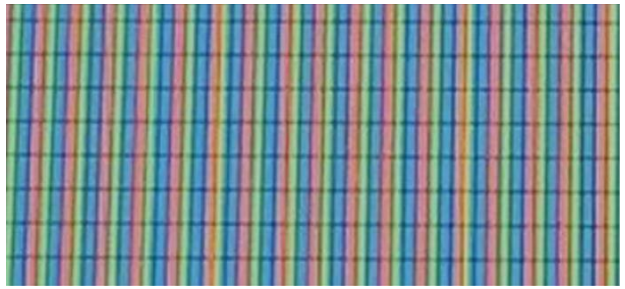
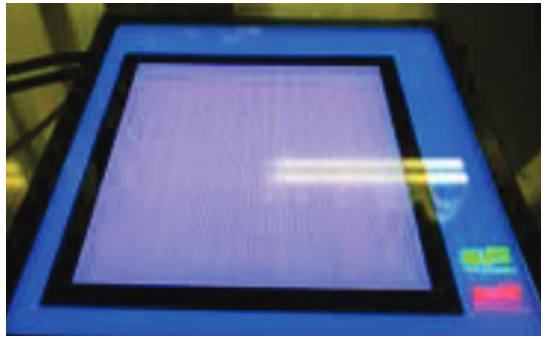


Fig. 3



Ref. Ravi Tangirala et. al. IDW 2017 Digest MEET 4-2 p.1330