

Investigation of Carbon Nanotube Ink with PDMS Printing Plate on Fine Solid Lines Printed by Micro-flexographic Printing Method

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Abstract. Micro-flexographic printing which is combination of flexography and micro-contact printing is a unique printing technique that create graphic, electronic and biomedical printed image on variable substrates. Therefore, an investigation for its potential usage in global area of printing hence a research for suitable ink and printing plate related to this process is vital. This paper will focus on investigating the printability of Carbon Nanotube (CNT) ink with polydimethylsiloxane (PDMS) printing plate. There are two types of CNTs ink which are solvent base and water base. A printing trial has been carried out in comparison with CNTs inks and PDMS printing plate with fine solid lines image on it to check the suitability of the printing plate development for micro-flexographic printing technique. The result shows that CNT water base ink is suitable with PDMS printing plate in printing fine solid lines image.

1. Introduction

Recently, researchers have shown that printing process play an important roles in producing the printed fine solid lines image especially in electronic industry. The research done by Zhang has investigated the manufacturability of organic electronics like organic field effect transistors (OFETs) using commercially available printing technologies and materials systems qualified for use in microelectronic products. The organic integrated circuits (IC) may be the low cost solution for driving electronic devices like smart cards, RFID tags, flexible displays and personal area networks. The material system selection for transistor structures and active layers is based on printing technology requirements [1].



Flexography printing process is a direct rotary printing that uses moulded printing die known as printing plate which is made from rubber or photopolymer. In a normal flexography machine design, there are multiple wheels that work in unison to pick up ink from an ink reservoir as shown in figure 1. Then, the ink will be delivered to printing die or printing plate. Lastly, printing plate will roll the ink onto product being mark or substrate [2].

Other than flexography printing method, micro-contact printing (μ CP) is a famous printing technique in producing product in micro or nano scale pattern. Micro-contact printing (μ CP) is performing by release patterns on a master polydimethylsiloxane (PDMS) stamp to form patterns of self-assembled monolayers (SAMs) of ink on the surface of a substrate through conformal contact like showing in figure 2. It is a low cost technique for the preparation of micro structure printing surface. PDMS is a suitable material for μ CP stamp because it has number of properties which well suit for μ CP process [3].

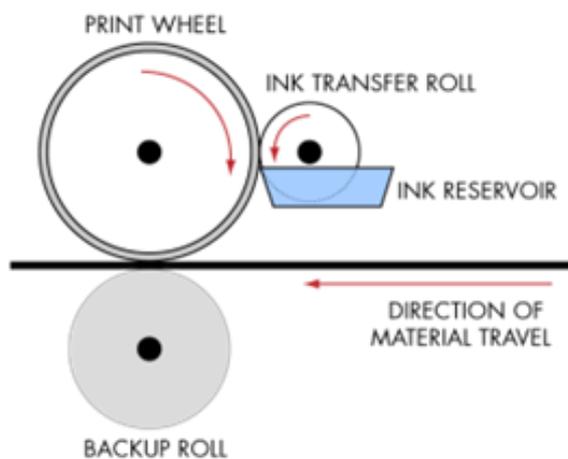


Figure 1: Flexography printing technique

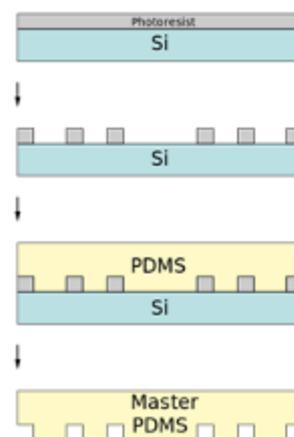


Figure 2: Micro-contact printing printing technique

Low cost material and production in producing electronic parts by printing process like flexography is very important. The photopolymer material as a printing plate in flexography printing process is unable to produce micron scale lines of features. Hence, PDMS can be used to replace the photopolymer as a new printing plate in flexography printing process. Printing trial has been conducted by previous researcher in using PDMS printing plate for printing fine line in micro scale pattern [4].

The printability of CNTs as a conductive ink had been performed by previous researcher in flexography printing process. The author managed to print fine solid line image pattern by the CNT ink on variable substrates such as silica, biaxially oriented polypropylene (BOPP), textile and paper. Simple experimental test of ink functional performance had been done by lighting up light emitting diode (LED) lamp. The author concluded that CNTs water base was the best ink for printing on variable substrates but maintains high electric conductivity [5].

The flexography printing method had a capability in printing fine solid lines image. The previous research [6] used roll to roll flexography printing technique which was web press industrial method, the author managed to print out fine solid lines image by using carbon graphic inks. This technique used photopolymer as a printing plate to transfer the ink from plate roller to substrate. It was a step forward of developing high speed printing in electronic with simple, rapid, low cost method, less waste and roll-to-roll capability [7].

The application of flexography printing process in producing fine solid lines image in micro or nano scale is not limited to create electronic part only. This printing technique can be also applied in

biomedical industry [8]. By utilizing the PDMS printing plate, cell culture can be printed onto flexible polymer substrate for bio-sensor making [9].

2. Research Methodology

In this study, there were two type of CNTs ink used for the fine solid lines printing trial. First ink was CNTs solvent base liked showing in figure 3. CNTs solvent base ink had 90% to 95% chemical composition of polypropylene glycol [5]. Second ink was CNTs water base as shown in figure 4. This type of ink had 80% to 90% composition of water. Both of the inks were supplied by Fuji Ink Industries Limited.



Figure 3: Carbon Nanotube (CNT) solvent base ink



Figure 4: Carbon Nanotube (CNT) water base ink

A pattern of multiple fine solid lines image of PDMS printing plate was prepared as shown in figure 5. PDMS printing plate had an advantage in producing micro, even nano-scale size in fine solid lines printing [10]. The PDMS was poured into the mould with the silicon wafer as a master image plate to get fine solid lines image with different size of width and distance gap. Figure 6 showed the PDMS printing plate with multiple fine solid lines image. The PDMS printing plate size was approximately 30 mm x 20 mm for length and width and 1mm thickness.



Figure 5: Silicon wafer master image

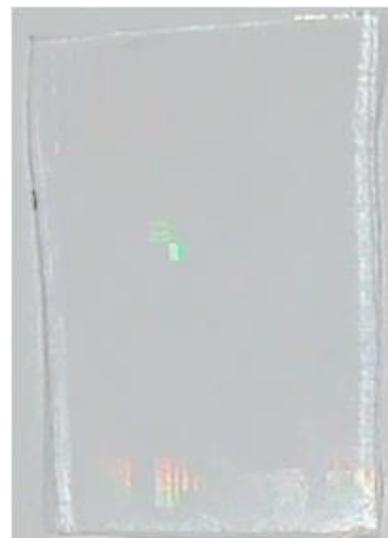


Figure 6: PDMS printing plate

The printing process was started with the preparation of customized micro-flexographic printing machine in laboratory scale as shown in figure 7. Micro-flexographic printing machine was a combination of flexography and micro-contact printing method [11]. Flexography was one of the fastest printing processes but it had limitation in micro to nano printing scale. Compared with micro-contact printing, it was very slow but can achieved micro to nano fine solid lines image. This combination printing method will have a high printing capability with high speed production, micro to nano scale image pattern and low cost production process.

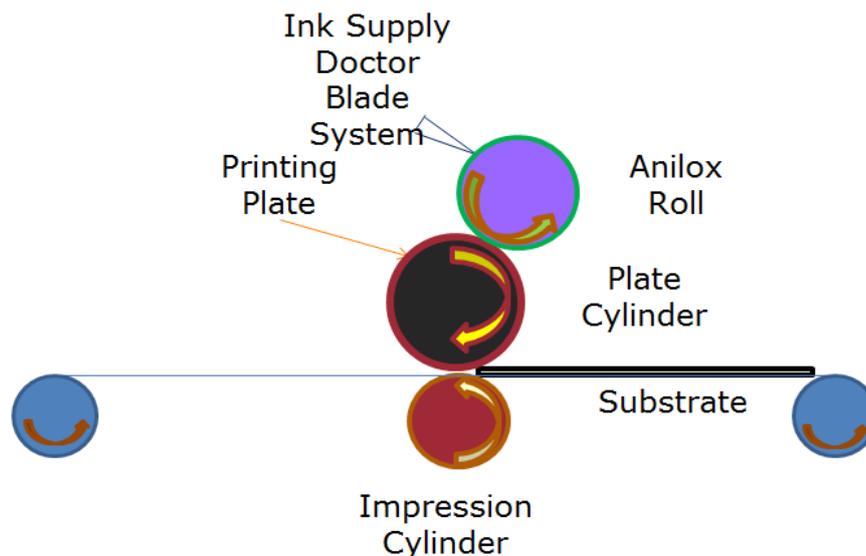


Figure 7: Schematic diagram of the micro-flexographic printing process

In this customize design apparatus, basic components of flexography printing machine liked impression cylinder, plate cylinder, anilox roll and doctor blade were replicated. Micro-flexographic printing process used the same concept liked flexography printing method. PDMS printing plate with multiple fine solid lines image was attached to the plate cylinder. The CNT ink was transfer to the PDMS printing plate by using an engraved cylinder roll which known as anilox roll. The anilox roll was the main control of ink transferred to the printing plate and substrate [12].

The printing capability was checked by adjusting printing parameters liked speed and roller engagement. All the parameters needed to be taken care during printing trial due to the aim of this project was very critical. In parameter setting approach, the speed was set at 15 rpm. All the parameters mention was set to get a good result in printing trial. The printed fine solid lines image was checked by common microscope known as Olympus BX60M. Technical specification of the microscope are 30mm/s speed, 0.1 μ m encoder resolution and below 2.0 μ m absolute accuracy. The result will show the direction of this study in meeting the objective.

2.1. The printed image analysis using microscope Olympus BX60M

The printed fine solid lines image was checked by using common microscope known as Olympus BX60M. Technical specification of the microscope were 30mm/s speed, 0.1 μ m encoder resolution and below 2.0 μ m absolute accuracy. This equipment was capable to check the line features including line width and gap.

3. Result and Analysis

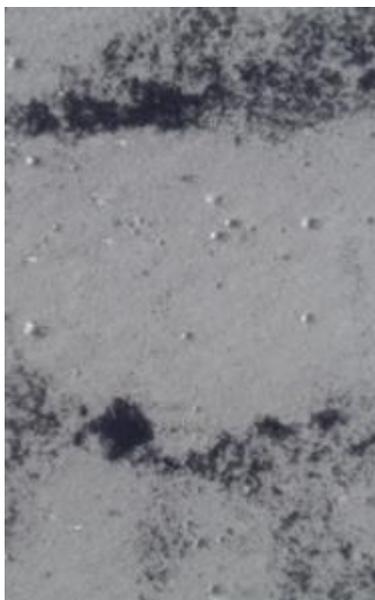
Experimental process for printing trials had been done to find the suitability between CNTs ink and PDMS printing plate which could be selected as preliminary result. All the experiment was ran by using micro-flexographic printing process. First printing trial was done on PDMS printing plate by

using CNTs solvent base ink. From the result, it showed that PDMS Printing plate was not suitable to be used with CNT solvent base ink. Figure 8 showed the evidence which the PDMS was damaged when both of the printing part or parameter were used together. CNT solvent base ink was caused the damaged of the PDMS surface of fine solid lines image.

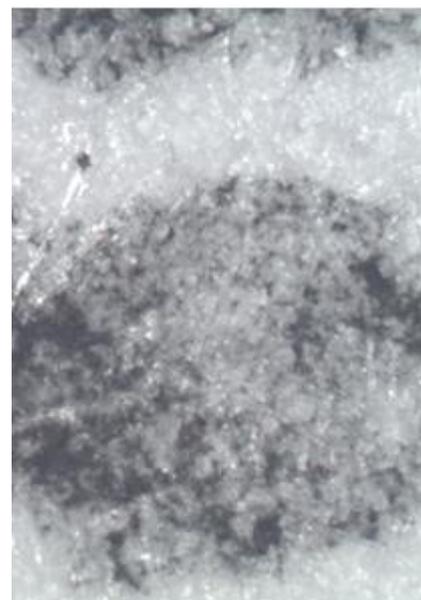


Figure 8: PDMS printing plate condition after being used with CNT solvent base ink

Second experiment of printing trial was done on PDMS printing plate by using CNT water base ink. The printing trial had been done successfully on paper substrate. The multiple fine solid lines pattern image printed result liked showing in Figure 9(a-d) depended on the viscosity setting. The ink viscosity was setting from low to high which was ratio between water and CNT ink. Figure 9(a) showed the lowest viscosity setting with unclear fine solid lines image. When the viscosity was increased, fine solid line pattern image will be more cleared as shown in Figure 9(d).



(a)



(b)

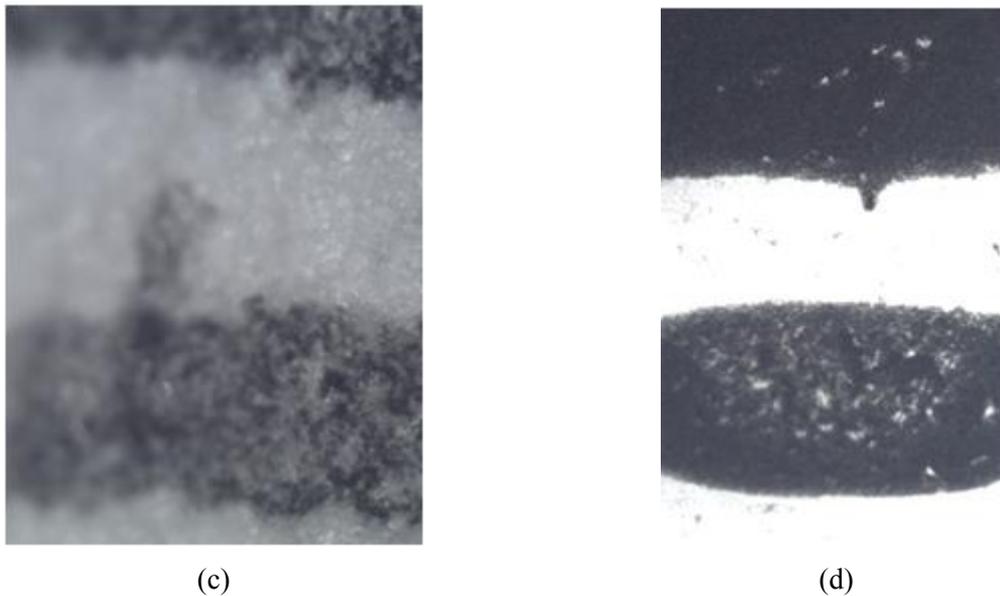


Figure 9: Result of viscosity changing in using CNT water base ink on the paper substrate: (a) Low viscosity (b) Moderate-1 viscosity (c) Moderate-2 viscosity (d) High viscosity

This result showed that micro-flexographic printing technique needed a high viscosity setting to get a good image pattern compared with micro-contact printing which needed a low viscosity setting for printing ink [13]. Other parameters which had significant effect on micro-flexographic printing process were machine parameters setting and substrate. The examples of machine parameters setting were machine speed and engagement between rollers. Those parameters were well manipulated so that good result could be achieved.

The fine solid lines image from Figure 9(d) was taken as the best result for line measurement analysis. The final result from microscope Olympus BX60M measurement was shown that the fine solid lines printed image width and gap size was 0.35 mm and 0.25 mm respectively. The measurement result of the printed image was depended on the fine lines image size on PDMS printing plate surface.

During the experimental printing process, there were several major concern involved. The concerns were printing speed, engagement, type of ink, ink viscosity and printing plate material. Some ink liked CNT solvent base cannot be used with polymer printing plate and ink viscosity will affect the best image result for measuring process analysis. Therefore, all those concerns needed to be investigated further in order to get better result in the future for printing development process.

4. Conclusion

From this study, several conclusions can be summaries as follow:

1. CNT solvent base ink is not suitable to use with PDMS printing plate.
2. CNT water base ink is suitable to be used with PDMS printing plate for printing purpose.
3. Ink viscosity is effected the image result. When the ink viscosity is increased, fine solid line printed image is more cleared and give good result for measuring process.
4. Micro-flexographic is a combination of flexographic and micro-contact printing has a good potential in printing fine solid lines image pattern for graphic, electronic and bio-medical purpose.
5. Micro-flexographic is a good candidate for fine solid lines printing with ink property, substrates and process parameters are main role to achieve the implementation.

Acknowledgments

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