A Study of Micro to Nano Structure Fine Solid Line Printing for Graphene Ink by Micro-flexographic Printing Method

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Abstract: - Flexography is one of the famous printing techniques that are possible to create graphic and electronic device on variable substrates by using conductive ink. Graphene is an example of material that can be used as printing ink which usually use in producing micro to nano scale electronic devices in a low cost production. Flexography is a high speed roll to roll printing technique commonly used in paper printing industry. And this study elaborates the analysis of graphene as a printing ink use in combination of flexography and micro-contact which known as micro-flexographic printing for micro to nano scale fine solid line image. Here, it is proposed that extending micro-flexographic printing technique into the multiple micro to nano scale printing fine solid line onto biaxially oriented polypropylene (BOPP) substrate by using graphene as a printing ink. This paper will illustrates the use of graphene in producing multiple fine lines printing capability for the application of printing electronic, graphic and bio-medical.

Key-Words: - Flexography, micro-contact printing, micro-flexographic, graphene, micro to nano scale, fine solid lines

1 Introduction

Recently, researchers have shown that all printing components like ink, printing plate, substrate and others, play an important roles in producing the micro to nano scale fine solid line image. Ink, subtrate and printing plate properties play the main role to achieve the best quality of printing which is fine solid line width and gap of below 10 µm. The example of ink properties are ink chemistry, viscosity, rheological behavior, solvent evaporation rate, drying and others [1].

Previous research by Maksud had discussed about flexography printing technique in using carbon nanotubes (CNT) as a new ink for printing purposes. There were two types of CNT inks which were water base and solvent base. The substrates were silica, biaxially oriented polypropylene (BOPP), white blank office paper and woven cloth had been used. The result concluded that CNTs water base ink was the best ink which can be printed onto many substrates with maintain high electric conductivity [2].

The previous research done by Yusof [3] stated that by using photopolymer as a printing plate image carrier in roll to roll printing technique which was web press industrial printing method, the author managed to print out 50µm line width and 50µm line gap by using carbon graphic ink as printing ink liked showing in Figure 1. This technique used photopolymer as a material in mold making which play a role to transfer the ink from plate roller to substrate.

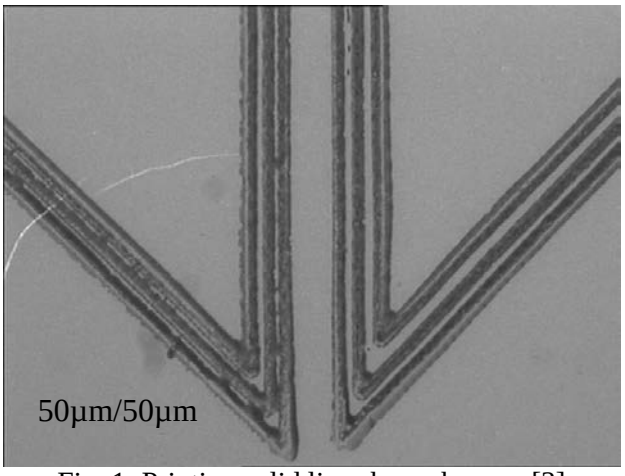

Fig. 1: Printing solid lines by web press [3]

Micro-contact printing (µCP) is a related printing technique in micro to nano scale pattern that manages to print fine solid line smaller than

flexography printing technique. Previous study by Perl show that µCP could produce fine solid line below 1µm liked showing in Figure 2 [4]. This work employed the modification of Polydimethylsiloxane (PDMS) printing plate to achieve high mechanical stability of the micro to nano structures and good capability to form conformal contact down to the nanometer scale despite potential substrate roughness.

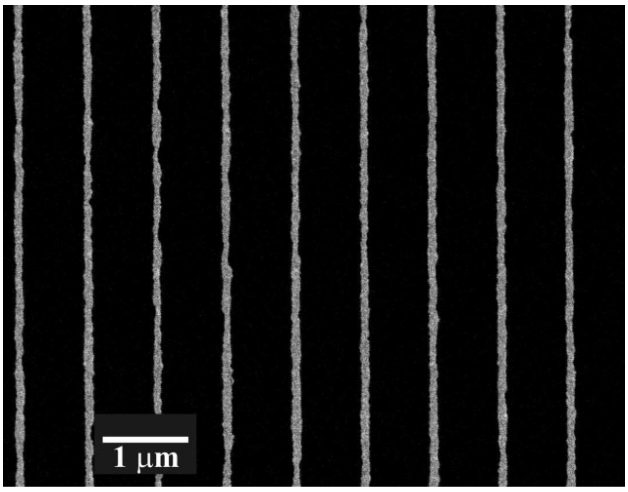

Fig. 2: Printing solid lines by µCP process [4]

The previous research in using PDMS printing plate for flexography printing process by Maksud shown that micro scale fine solid line was succesful printed. The research was focused on the developement of low cost mass production UHF (Ultra-high Frequency) passive RFID (Radio Frequency Identification) sensor for biomedical liked monitoring the movement of healing limbds to warn about too large movement and for monitoring chest breathing movements. The key factor from the research were changing photopolymer which was normally used in µCP printing to become a printing plate for flexography printing process [5].

Micro-contact printing and flexography printing technique have its own benefits in micro to nano printing pattern. The combination of both printing techniques will expand a new era of printing technology that can be explored in all aspects. The knowledge gap in printing plate preparation, engage contact mechanism, ink spreading mechanism and other important factors are still under further development. Previous work by Maksud et al had demonstrated that a 10 µm line width with 10 µm line gap was successfully printed as shown in Figure 3 by emerging the two combinations of printing techniques while using PDMS material as printing plate [6]. This achievement was attributed to the PDMS plate making technique while improving the slow production and low productivity of µCP printing techniques to be faster and excellent registration control in flexography roll to roll printing techniques.

Ink is one of the important parameter in printing technique. Le et al. have discussed about graphene supercapacitor electrodes which known as electric double layer capacitor electrodes that was fabricated by inkjet printing [7]. Figure 4 showed the circular Graphene Oxide (GO) dot as that produced with 20 printing passes at 20 min interval between passes. The research had approved that hydrophilic GO dispersed in water was found to be a stable ink for inkjet printing of GO with the lateral spatial resolution of 50µm.

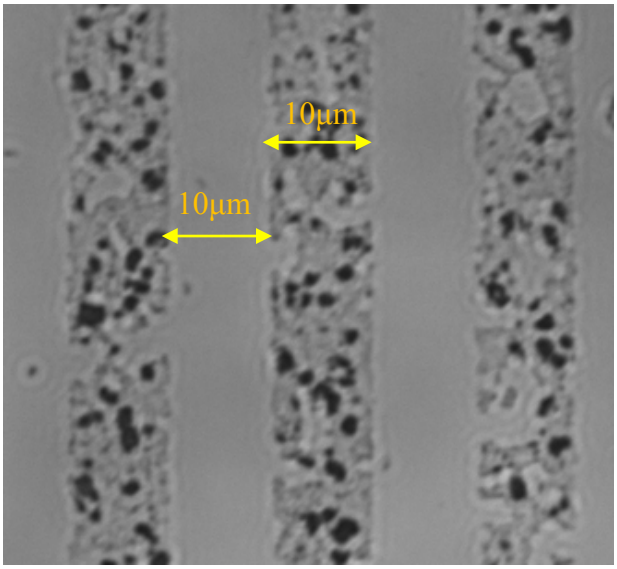

Fig. 3: Printing solid lines by µCP and flexography [6]

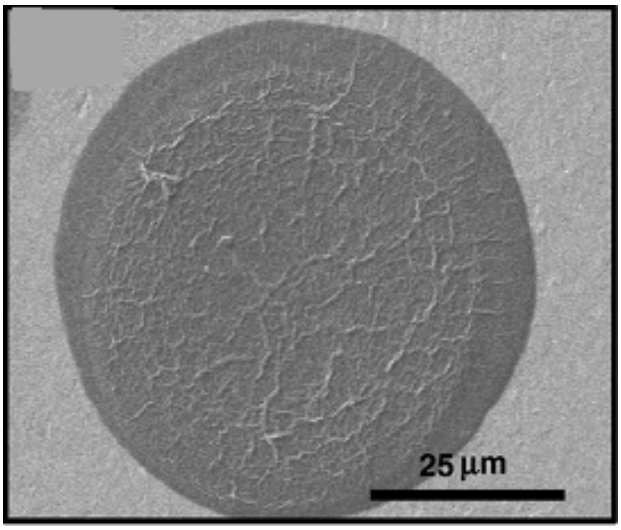

Fig. 4: Graphene Oxide (GO) dot printed on the Ti foil [7]

The succesful developement of combination micro-contact and flexography printing technique

will lead to mass production and low cost of printed electronic devices. The micro-flexographic printing technique could be applied for flexible, bended or rolled consumer product liked a LCD display, printed RFID antenna and others [8]. The PDMS printing plate also can be expand not only in electronic industry but also in graphic and bio-medical purpose.

Furthermore study into combination of flexography printing and µCP, the suitable of parameters setting was one of the most important issue [9]. This study was discussed about printing parameters that will affect the printing capability. Besides that, both of the printing techniques need to be understood well. The main target of the study is to run the printing experimental by using graphene ink and PDMS material as printing plate that has been used in µCP to be employed in the combination of flexography printing and µCP to achieve the printing of multiple fine solid lines on substrate below than 5µm. This study of micro to nano fine solid line structure will be applied not only in graphic and electronic but also for biomedical purpose [10].

2 Research Methodology

The printing process was started with the development of customized micro-flexographic printing machine in labaratory scale as shown in Figure 5. Micro-flexographic printing machine was a combination of flexography printing and micro-contact printing technique. Flexography was one of the fastest printing process but it had limitation in achieving micro to nano printing scale [11]. Compare with micro-contact printing method, it was slowed but it could print fine solid line image down to nano scale. The combination of both printing technique will lead to new era of high speed printing machine that could print micro down to nano scale image expecially in fine solid line image for electronic and bio-medical purpose.

The basic components of flexography printing machine liked impression cylinder, plate cylinder, anilox roll and doctor blade were remained. Micro-flexographic printing machine also used the same concept like flexography machine process. A pattern of multiple fine solid line image was designed on the stamp plate or printing plate which was attached to the plate cylinder. In micro-flexographic printing process, ink was transferred to the printing form using an engraved cylinder known as an anilox roll which consists of finely engraved cells [12].

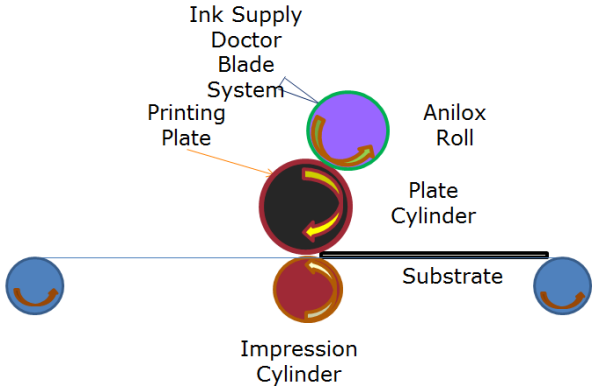

Fig. 5: Schematic diagram of the micro-flexographic printing process

Afterthat, the Polydimethylsiloxane (PDMS) printing plate was prepared by using acrylonitrile butadiene styrene (ABS) material as master mold. 3D printer machine which known as rapid prototype machine was used to build the master mold. Then, the PDMS was poured into the master mould with the silicon wafer that already inside the mould like showing in Figure 6. The silicon wafer was used as micro to nano scale image to get the fine solid lines for width and distance gap below 5µm.

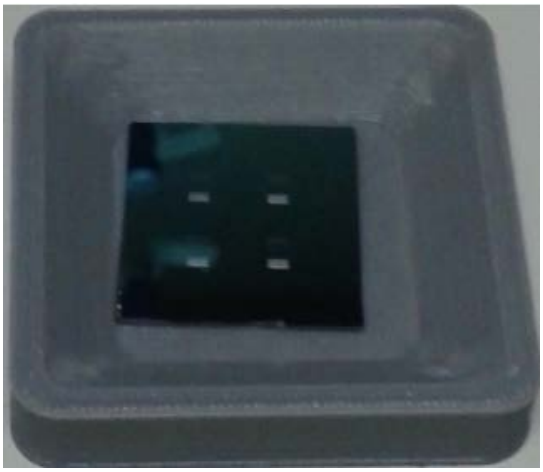

Fig. 6: Original multiple fine solid lines pattern on silica wafer was placed in master mold

The main target of this study was to achieve fine solid line printed image below 5µm which was never been achieve in flexography printing technique. The size of the mould was defined the quantity or thickness of PDMS. Some bubbles were appeared during pouring which was removed by vacuum pump. Figure 7 showed the completed PDMS printing plate with fine solid lines image on the surface in range 10 µm down to 1 µm width. The PDMS printing plate was then attached to the micro-flexographic printing machine to start the printing process. A good quality image of fine solid line on PDMS printing plate surface will lead to the

high quality fine solid line image on printed substrate.

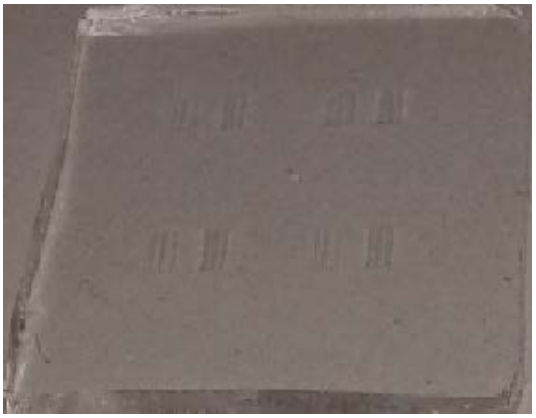

Fig. 7: PDMS printing plate

The printing capability was checked visually by adjusting processes parameters like engagement between anilox and plate cylinder, engagement between plate cylinder and impression cylinder and speed. These parameters were taken care during experiment due to the aim of this project are very critical in printing micro to nano fine solid lines image.

Graphene ink was affectively used for these combination of flexography and micro-contact printing which known as micro-flexographic printing method for micro to nano fine solid line scale image which newly developed method to deposit and pattern them over large areas and at higher resolution [13]. The study also stated that ink effects were viscosity, solvent and ink particle size that will affect the final result.

3 Result and Analysis

Experimental process was started by doing several printing trial by using micro-flexographic printing machine. The substrate used was biaxially oriented polypropylene (BOPP) film and graphene material as a low cost ink usually used in micro-electronic industry. The PDMS printing plate pattern image comprises solid fine lines image range from 10 µm down to 1 µm was successfully fabricated from the silicon wafer image. This PDMS printing plate was designed in various fine straight lines width so that the printing trials in the future could be analyzed and gave several different results for comparing. From several types of different fine solid lines width, lines with 3 µm width and 3 µm gap was chosen due to minimum line width with clear lines fabricated liked showing in Figure 8.

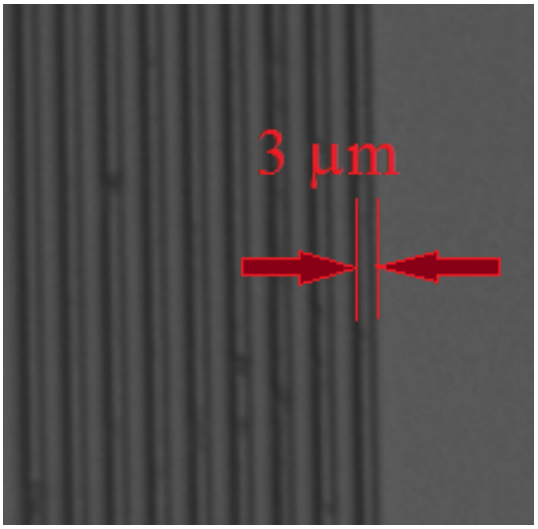

Fig. 8: PDMS printing plate with fine solid line 3 µm width and 3 µm gap

The printing result showed that the 3 µm width and 3 µm gap fine solid lines image were successful printed and achieved as shown in Figure 9 which was never been done previously by flexography printing method. From previous research, the best result in fine solid lines image printing was claimed by Maksud et al which were 10 µm width and 10 µm gap by using Fetal Bovine serum and graphic ink [6].

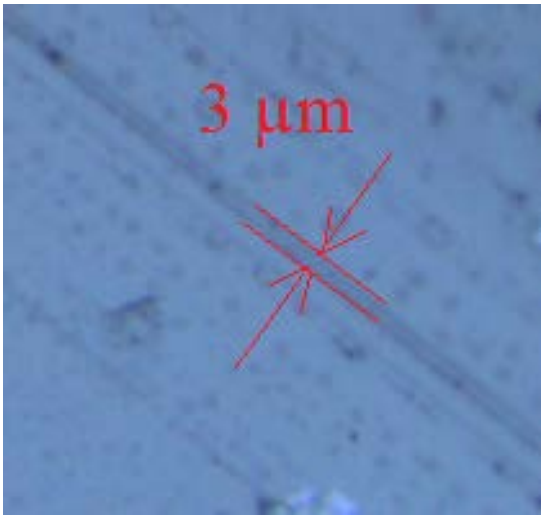

Fig. 9: Printed fine solid line image of graphene ink with 3 µm width and 3 µm gap scanned by Olympus BX60M microscope

During printing trial, there were several concerns that must be considered. The concerns were the machine parameters setting which were engagement between anilox and plate cylinder, engagement between plate cylinder and impression cylinder and lastly the speed. Those items were manipulated to achieve fine solid lines image as the good result.

4 Conclusion

The study in printing process of micro-contact and flexography printing is essential towards the combinations of both printing techniques prior to use graphene as ink. The combination of both printing technique which known as micro-flexographic printing technique was successful in producing the lowest line width and gap. This new printing technique could print 3 µm width and 3 µm gap fine solid lines image on BOPP substrate by using graphene as printing ink medium. This achievement was a step to move forward in order to achieve high speed printing in electronic with simple, rapid, low cost method, less waste and roll-to-roll capability.

The study of graphene rare earth metal as a printing ink that used in combination of flexography and micro-contact printing in producing multiple fine solid lines are due to the success in other printing techniques such as ink jet printing. This work was practically used in electronic printing industries that aimed on printing multiple solid lines from micro to nano size where it can also be applied in other printing industries like graphic printing and bio-medical purposed.

5 Acknowledgement

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