CONTROL OF REGISTRATION ACCURACY OF R2R GRAVURE FOR FABRICATING INEXPENSIVE ELECTRONIC DEVICES

By

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ABSTRACT

The errors of the overlay printing registration in roll-to-roll (R2R) gravure are generated from many sources such as uneven web tension, thermal expansion and contraction of plastic web, uneven impression roll pressure, slipping the web, uneven circumference of the roll, unmatched speed between web transfer, printing roll, and so forth. Among those things, the most influential factors to exert on overlay printing registration in R2R gravure should be defined and analyzed to provide servomechanism to control at least ±20 µm of registration accuracy of R2R gravure with more than 4 m/min of web transfer speed. In this paper, we would like to present the general way of control system of R2R gravure to maintain the overlay printing registration of ±20 µm under various web transfer speeds, roll pressure and uneven web tension.

INTRODUCTION

Roll-to-roll (R2R) gravure has been employed recently in the field of fabricating low cost electronic devices such as RFID tags, sensors and signage depending on the level of improving registration accuracy of R2R gravure[1]-[4].

The thickness, morphology and registration accuracy of the printed layers are affected by web tension, surface wetting, printing speed, drying temperature, impression roll pressure and groove cell structures which can influence on the properties of the printed devices especially for printed thin film transistors[5]-[7] since the functions of printed devices will be severely deteriorated by degree of registration accuracy of printed each layers. Therefore, it is indispensable to increase the registration accuracy of R2R gravure to provide highly functional gravure printed electronic devices. In fact, the overlay printing registration accuracy should be well controlled up to at least 20 µm to start employing R2R gravure for printing low functional electronic devices on plastic webs.

influential factors to keep ±20 μm of registration accuracy. This servomechanism of R2R gravure system has been designed to control the rotating speed and lateral movement of the second printing roll for accurately matching the previously printed markers to the markers on the second gravure roll at the nip point of the second printing unit. Based on this, we can propose the general way to maintain the overlay printing registration of ±20 μm under various web transfer speeds, uneven web tension and roll pressure of R2R gravure.

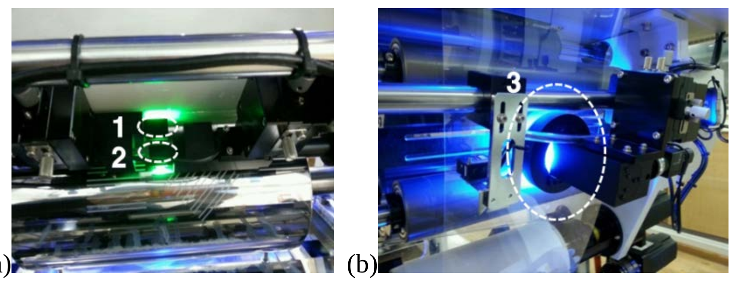
EXPERIMENTS

R2R gravure printing has been carried out on corona treated poly(ethylene terephtalate) (PET) foils (SKC, Korea) with a thickness of 100 μm and width of 250 mm using a commercially available R2R gravure printer (iPen, Korea), shown in Fig. 1. Gravure printer was equipped with two printing units. The first printing unit is used to print gate electrodes and then, the second printing unit is used to print dielectric layers in R2R inline process. Silver nano particle-based conductive inks with viscosity of 400 cP (SV-10 VIRO Viscometer, AND Co., Japan) were formulated for R2R gravure printing of gate electrodes on PET using Ag nano-gel (PG-007, PARU Co., Korea). The $BaTiO_3$ based dielectric ink (PD-100, Paru Co. Korea) was formulated with viscosity of 160 cP as dielectric layer to print on previously printed gate electrode layer. All the gravure printing process was carried out using the gravure cylinders (Yung Duck Co., Korea) engraved structures with a laser stream process.

Gravure printer was equipped with two CCD cameras (FC) in front of the second printing unit in order to measure markers on film and gravure cylinder. The measurement of the overlay printing result was carried out one CCD camera (BC) behind the second printing unit. The servomechanism for controlling the overlay printing registration of R2R gravure was introduced by attaching high resolution CCD camera and optical devices to detect the markers printed at the first printing unit and then, controlling the rotating speed and lateral movement of the second printing gravure cylinder for matching the previously printed markers to the markers on the second printing gravure cylinder.

The gravure printing was carried out under drying temperature of 150 and 120 ℃ respectively for the first and second drying chambers with web tensions (0.5 and 1 N), printing roll pressures (0.6, 0.8 and 1 MPa), and web transfer speeds (6, 8, and 10 m/min).

Figure 1 – Actual image of the R2R gravure machine with two printing units

(a) 

(b)

Figure 2 – (a) Two CCD cameras in front of the second printing unit. 1 and 2 are the cameras to search printed marks at the first printing unit on film and marks on printing gravure cylinder, respectively. (b) One CCD camera behind the second printing unit to measure the overlay printing accuracy.

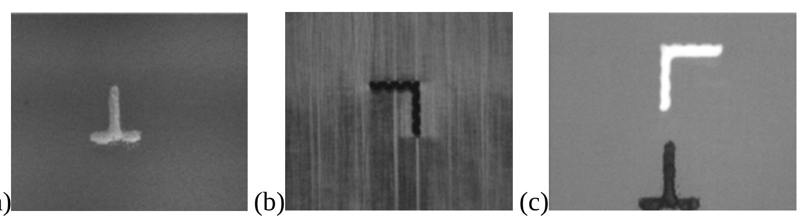
(a) 
(b) (c)

Figure 3 – (a) Mark image on film captured with camera 1 of Fig. 2 (a). (b) Mark image on printing gravure cylinder captured with camera 2 of Fig. 2(a). (c) Two mark image on film captured with camera 3 of Fig. 2(b).

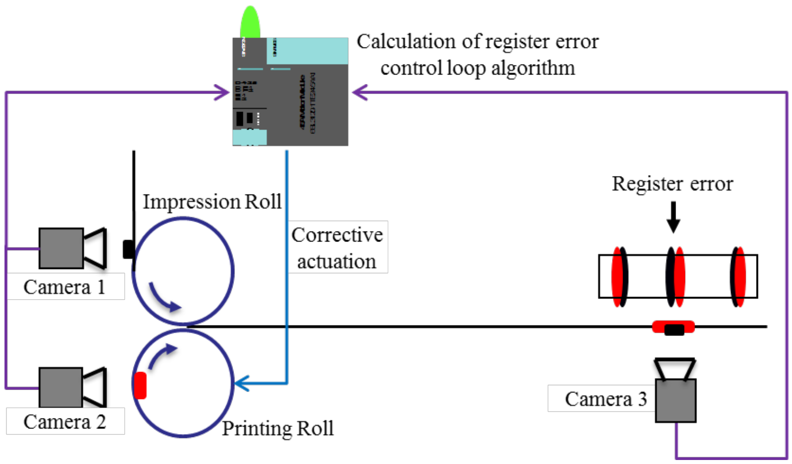


Figure 4 – The schematic diagram of real time feedforward compensation using CCD camera system. Camera 1 and 2 will capture the mark images on both film and printing roll before printing. Camera 3 will capture the overlay printing image of marks.

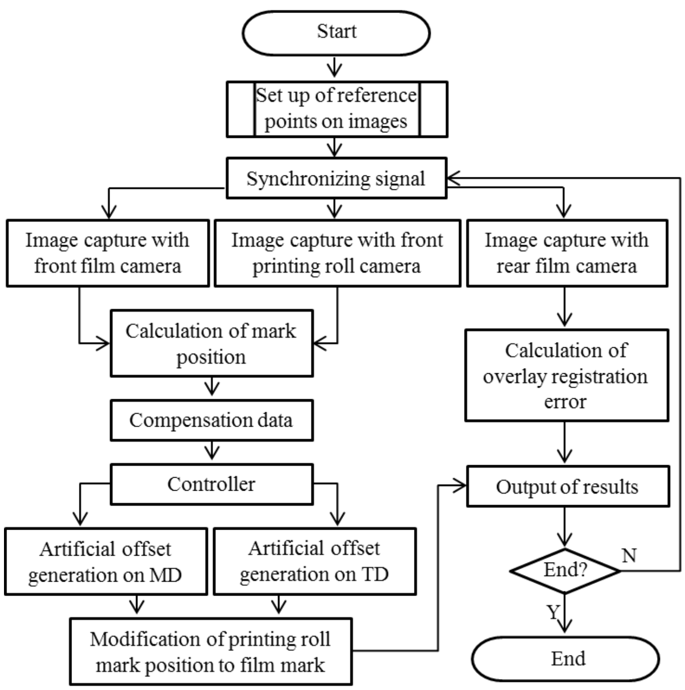


Figure 5 – The general flow chart of controlling overlay registration accuracy with high precision on machine direction (MD) and transverse direction (TD).

RESULTS AND DISCUSSION

After printing second layers, we measured the distance between the first layer mark and the second layer marks along both the machine direction (MD) and transverse direction (TD) with the BC. Fig. 6–11 show the measured registration errors of the two printed layers in the MD (Fig. 6-8) and TD (Fig. 9-11).

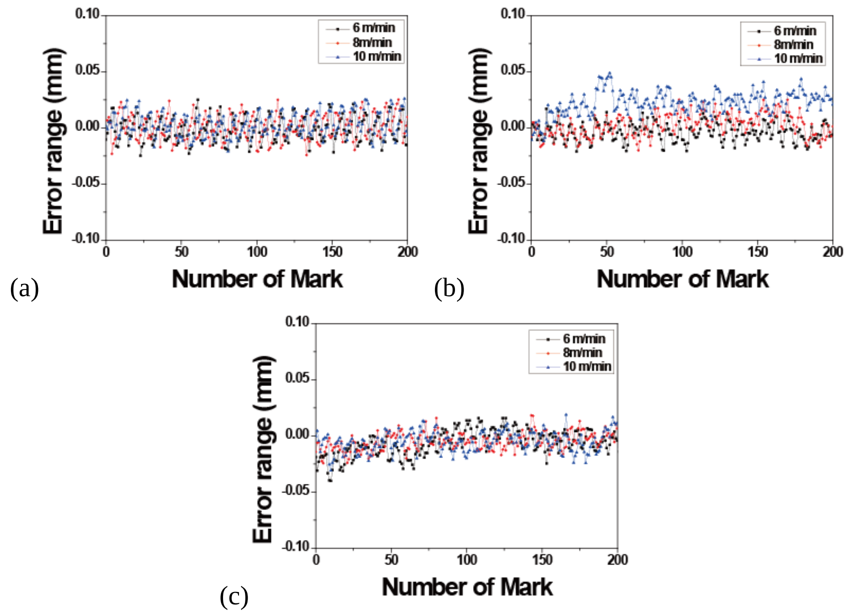


Figure 6 – Overlay registration error for machine direction under web tension of 0.5 N, web transfer speed of respectively 6, 8 and 10 m/min, and printing roll pressure of respectively 0.6 (a), 0.8 (b) and 1 MPa (c).

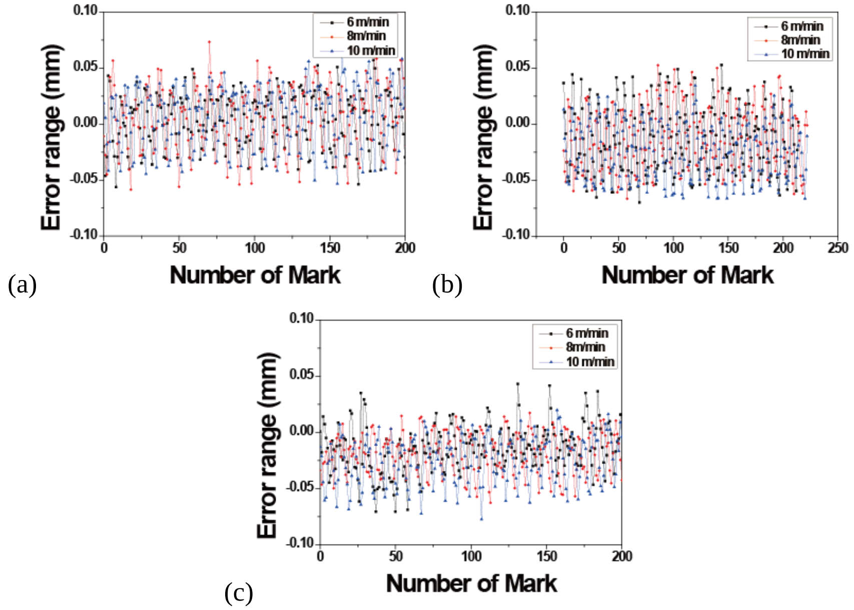


Figure 7 – Overlay registration error for machine direction under web tension of 0.75 N, web transfer speeds of 6, 8 and 10 m/min, and printing roll pressures of 0.6 (a), 0.8 (b) and 1 MPa (c).

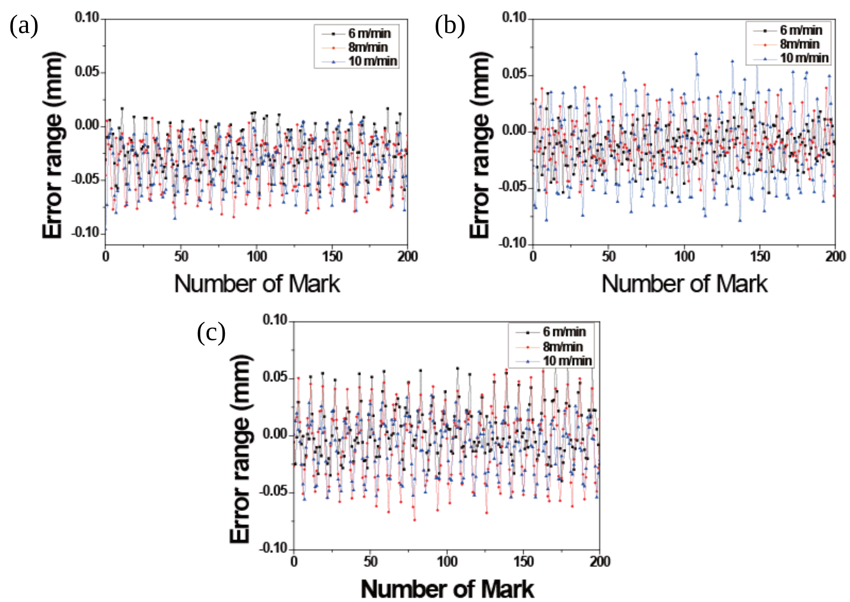


Figure 8 – Overlay registration error for machine direction under web tension of 1 N, web transfer speeds of respectively 6, 8 and 10 m/min, and printing roll pressures of respectively 0.6 (a), 0.8 (b) and 1 MPa (c).

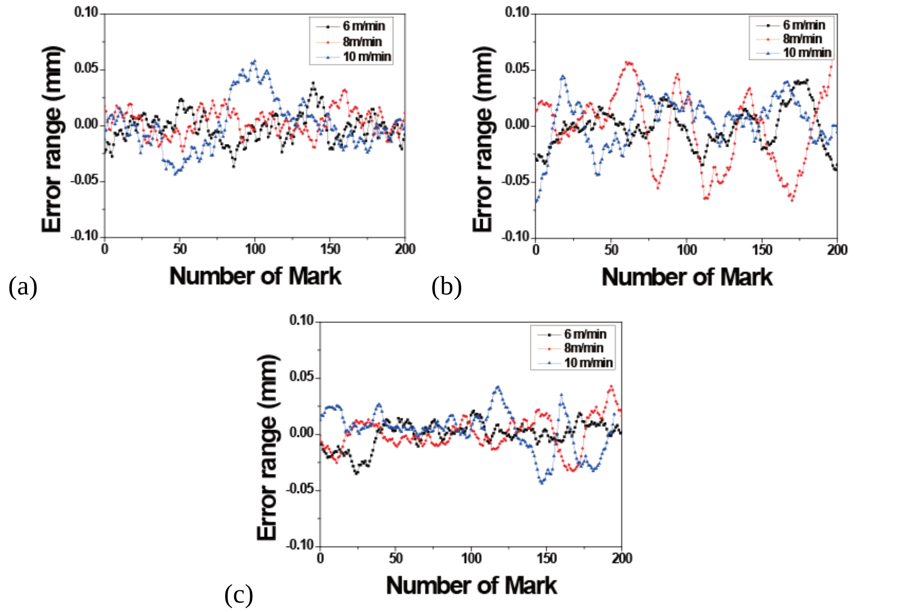


Figure 9 – Overlay registration error for transverse direction under web tension of 0.5 N, web transfer speeds of respectively 6, 8 and 10 m/min, and printing roll pressures of respectively 0.6 (a), 0.8 (b) and 1 MPa (c).

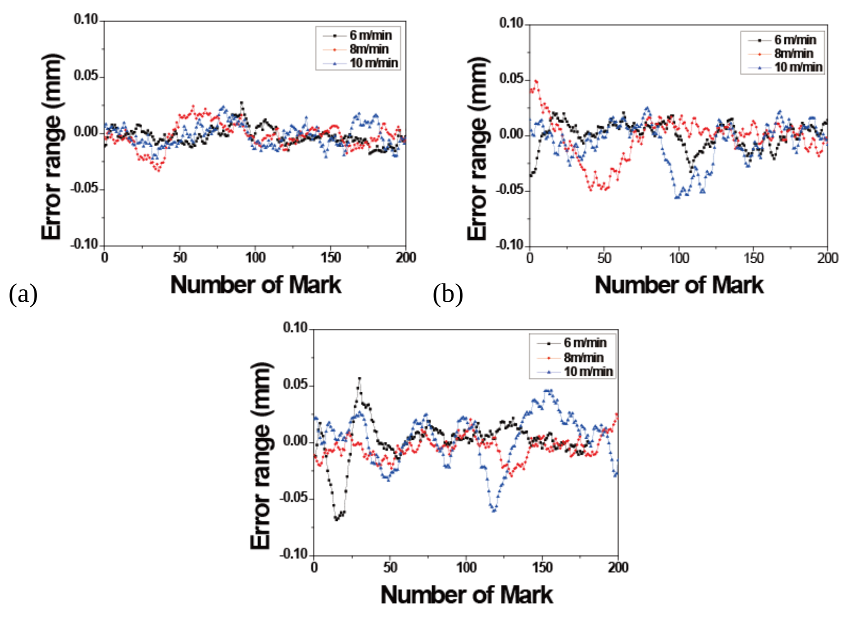


Figure 10 – Overlay registration error for transverse direction under web tension of 0.75 N, web transfer speeds of respectively 6, 8 and 10 m/min, and printing roll pressures respectively of 0.6 (a), 0.8 (b) and 1 MPa (c).

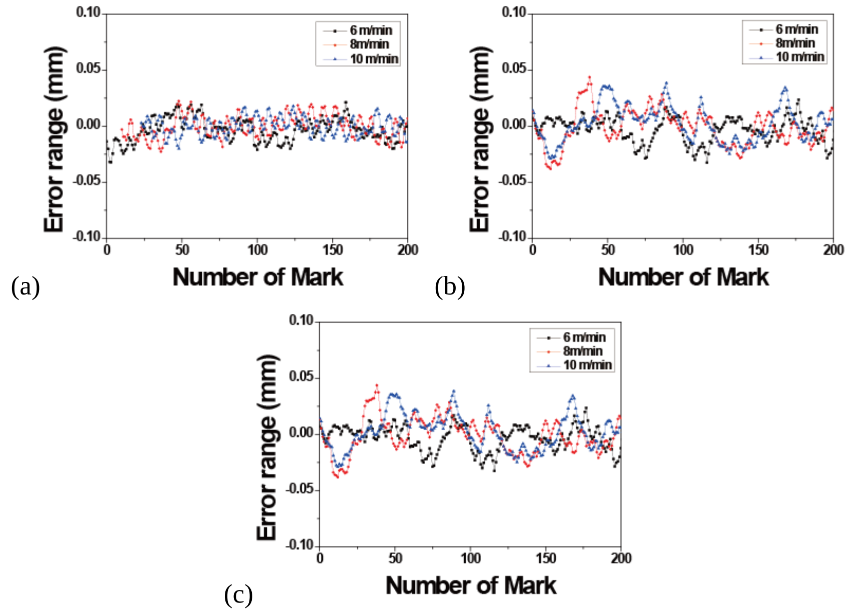


Figure 11 – Overlay registration error for transverse direction under web tension of 1 N, web transfer speeds of respectively 6, 8 and 10 m/min, and printing roll pressures of respectively 0.6 (a), 0.8 (b) and 1 MPa (c).

In this experiment, since controlling the rotating speed and lateral movement of the second gravure roll to accurately control registration of MD and TD has been also affected by key factors such as overlay registration error, web tension, printing pressure and web speed, the degree of influences by the key factors on controlling the registration accuracy of MD and TD were different.

Overlay registration error on MD was mostly affected by web tension among the other key factors. Furthermore, under the same web tension, overlay registration error was increased as printing pressure was raised. Overlay registration error was considerably decreased under web tension of 0.5 N and measured as < ±20 μm under printing pressure of 0.6 MPa and all web speed conditions as shown the results in Fig. 6.

Overlay registration error on TD was affected the most by printing pressure than by web tension, unlike MD. Under the same web tension, overlay registration error was also increased as the printing pressure was raised. The attained phenomena in this R2R gravure system are depending on frictional resistance between printing cylinder and impression cylinder. The overlay registration error of TD was measured as approximately ±20 μm under web tension of 0.75 N, and printing pressure of 0.6 MPa under all web speed conditions as shown the results in Fig. 10.

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