How to maximize the registration accuracy in R2R processing

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ABSTRACT

High registration accuracy in roll-to-roll (R2R) processes enables high throughput production of complex multilayer devices in printed and flexible electronics. Three different topics need to be optimized, in order to maximize the registration accuracy: i) stability of the substrate dimensions, ii) mechanical accuracy of the printing press, and iii) software to handle the web tension and position. We will show how all of these three topics can be improved to allow 15-20 µm registration accuracy even for rotary screen printing.

Keywords: Web handling, R2R printing, registration accuracy.

1. INTRODUCTION

Most of the printed electronics applications require accurate positioning of the different layers, *i.e.* high registration accuracy. For coating processes, only cross direction registration is necessary. For printing processes, we need to control both the cross direction and machine direction registration.

We will show how to reach registration accuracy of 15-20 µm, using rotary screen printing as an example. The study was performed at the pilot printing line at VTT's PrintoCent pilot factory facilities. Rotary screen printing was selected as the processing method since it is used in several applications, *e.g.* for organic solar cells and transistors, but it is also the most challenging printing method regarding registration due to the limitations in the printing resolution.

2. RESULTS

2.1 Substrate optimization

Dimensional changes during processing are potentially a problem if there are a series of stages, which involve heating under tension. For example, in processes where a series of patterns of specific dimensions is printed onto a PET sheet, then only very small dimensional changes between processing stations can be tolerated, or there will be registration issues with subsequent printed patterns. In this case, if all processing stages are at the same temperature and tension, then the (majority of) dimensional change will occur only in the first processing stage. In other words, the length of the film under tension at ambient temperature before and after each stage will change only through the first processing station, and not subsequent ones, as demonstrated in the findings of this study. [1]

Hence in some cases – when the dimensional change in the first or later stage cannot be afforded - it is recommended to pre-treat a substrate at the highest elevated temperature and tension it will subsequently encounter in the process, prior to processing it for the application. This will help to reduce the dimensional changes: We can achieve as low as 0.002% change in the machine direction if such pre-treatment is used, compared to a 0.3% change without the pre-treatment.

2.2 Hardware and software optimization at the pilot line

For following and adjusting the registration, we need to have suitable cameras in a correct position/angle vs. the substrate, allowing detection of the printed registration marks, usually a set of dots. The illumination unit of the camera contains different LED lights, and it is possible to change the color for the LED, improving the detection of the printing ink. In addition, for correct sampling of the register mark, the exact speed of the substrate needs to be known, so that the camera can synchronize to this speed. This is done by direct coupling of a rotary encoder to the roller. In addition, the systematic errors (even in the range of 100 µm) in the printing screen itself need to be taken into account.

Our previous registration control system was able to give 52 µm accuracy in the machine direction and 25 µm accuracy in the cross direction. By improving the software and the camera setup, our new system is able to achieve 15 µm accuracy in the machine direction and 18 µm accuracy in the cross direction, as shown in Figure 1. This register accuracy was achieved in less than 1 minute after the printing run was started. As the dot edge fluctuation in screen printing is of magnitude +/- 10-20 µm, it can be concluded that the achieved register error accuracy is very near the best achievable with the used printing technique. [2]

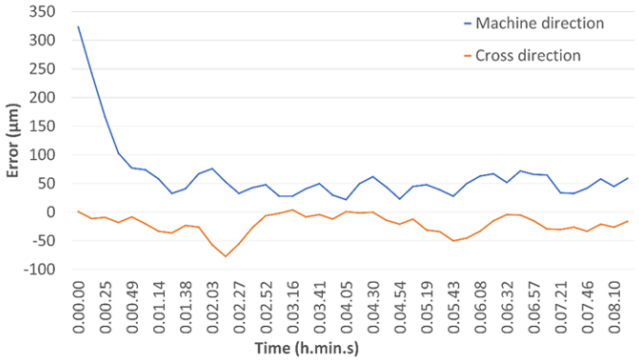

Figure 1. Register error after optimization of the registration software and hardware at the pilot printing line, using rotary screen printing as an example.

3. CONCLUSION

Proper registration of R2R printed layers enables production of electronic multilayer components. With accurate registration, we can print smaller structures, and improve the yield in the whole roll. In addition, with optimized software, we can achieve good registration already in less than 1 min from the start, enabling quick changes from a roll/layout to another, leading to faster production times and less waste.

In this work, we show how to optimize the substrate, and the software and hardware at the pilot printing line, in order to achieve 15-20 µm registration accuracy for a rotary screen printing process.

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[2] New, unpublished results by the authors.