Application of a grey-based Taguchi method for optimizing calendering process

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Abstract

Calendering process is a finishing process used widely for fabric and paper substrates. This process improves qualities such as glossiness and smoothness by applying a suitable heat and pressure to products. Recently, studies of calendering process have been extended to printed electronics process.

In general, calendering process has three factors: roll temperature, speed, and nip pressure. In this study, the three factors were optimized to obtain the best performance indices of multi-response of the bottom-gate, bottom-contact OTFT(Organic Thin Film Transistor), i.e. on-off ratio and field effect mobility. Because Taguchi method can be used only for analysis on a single-response, grey relational analysis that transfers multi-response problems into single-response is employed. For each factor of calendering process, three levels were set: temperature of 60, 80, 100 ℃, speed of 2, 4, 6 m/min, pressure of 41, 82, 123 kN/m. Though total experimental sets require 3^3(27), the number of experimental sets was reduced to 9 sets by using Grey-based Taguchi method.

Surface roughness of the gate dielectric layer of OTFT affects largely on on-off ratio and field effect mobility. In addition, surface roughness of the gate layer that is printed under the gate dielectric layer has also a large effect on the surface roughness of gate dielectric layer. Therefore calendering process was applied to both gate and gate dielectric layer to achieve the largest reduction of surface roughness of gate dielectric layer. In Taguchi method, there are three performance characteristics: ‘smaller-the-better’, ‘nominal-is-best’, and ‘larger-the-better’. Because this work is focused on maximizing the on-off ratio and the field effect mobility, ‘larger-the-better’ performance characteristic was selected.

As a result of grey relational analysis, an optimal set of calendering process parameters was obtained 100 ℃, 6 m/min, 82 kN/m for the gate layer and 100 ℃, 2 m/min, 123 kN/m for the gate dielectric layer. Three samples for each non-calendered and calendered OTFT samples were fabricated and performance data were obtained by taking measurements to quantify the calendering effects. As for calendered OTFT samples, calendering process with optimal sets were applied to both gate and gate dielectric layer.

The average values of surface roughness, on-off ratio, and field effect mobility were compared. The average of surface roughness of gate dielectric layer, on-off ratio, and field effect mobility of the non-calendered OTFT samples was 26.4 nm, 3.9×10^4, and 0.0341 cm^2/Vs respectively. As for calendered OTFT samples, we obtained 31.4 nm of surface roughness of gate dielectric layer, 4.5×10^4 of on-off ratio, and 0.0445 cm^2/Vs of field effect mobility. The result means 15.92% decrease in the surface roughness, 15.46% increase in the on-off ratio, and 30.50% increase in the field effect mobility. Therefore the grey-based Taguchi method provides a useful method for optimizing calendering process as well as reducing the number of experimental sets.

Keywords: Taguchi method, grey relational analysis, calendering process, optimization, OTFT