The study of light guide plate fabricated by inkjet printing technique

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\textbf{ABSTRACT}

When molding thin light guide plates, high injection speed and high molding pressure are required to fill the mold completely, but it is easy to have parts with defects like high residual stress and high warpage. Inkjet printing is a drop-on-demand (DOD) and direct writing process, there is no need to fabricate stampers for the DOD processes thus it saves lots of time on the development of light guide plates. With those benefits, back light unit suppliers around the world have envisioned the DOD process as a great potential for fabricating thin light guide plates. The aim of this study is to develop a complete light guide plate fabrication process using inkjet printing technology. That includes ink selection, substrate surface treatment, microlens array design, printing process parameters determination, and printing qualities investigation. A Dimatix DMP-2800 inkjet printing machine is used for printing the microlens and a polyacrylamide-based ink is selected. To make the PMMA substrate more hydrophobic, it is coated with a thin Teflon layer before the printing process. For this specific combination of machine, ink and substrate, when the distance between inkjet nozzle and substrate is 0.7 mm and the driving voltage is 12 V the printed microlens has the best quality. Referring to the microlens size of light guide plates made by industry, the microlens with 38 \( \mu \text{m} \) in diameter and 26 \( \mu \text{m} \) in height are selected for this study. A 3\( ^\text{rd} \) light guide plate, designed with TracePro software, is successfully fabricated using the proposed ink-jet printing scheme. The optical measurement result indicated that the light guide plate has an averaged luminance of 1012.58 nits and a luminance uniformity of 83.85\%. Thus work demonstrates the feasibility and effectiveness of utilizing inkjet printing technique to prepare light guide plates with low cost.

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1. Introduction

Due to its excellent properties such as light weight, low power consumption, and high image quality, the thin film transistor liquid crystal display (TFT-LCD) is used widely in the industry of electronic information displays, including television, mobile phones, personal digital assistant (PDA), notebook, portable information apparatuses, digital camera, etc. Because liquid crystals do not emit lights by themselves, a backlight system is adopted and placed behind the display to provide the emissive light for the LCD. A backlight system is composed of a light source, a light guide plate (LGP), and various layers of reflective, diffusive, and optical prism films [1]. The LGP guides the direction of the light in order to improve brightness and uniformity. Therefore, the LGP is an important key component for backlight module and light output. Brightness as well as uniformity all depends on design and fabrication of LGP [2]. The light guide should have the micro-optical pattern which is based on optics in order to change the direction in which the light travels. In the conventional designs, the light guides have a specific pattern of diffusing white spots on the bottom surface, where the diffusing dot pattern serves to spread the incident light from sources over a wide angle to keep the luminance uniform over the entire display area. The diffuser dots of a light guide are generally arranged in one of two basic patterns: a regular dot arrangement [3] or a random dot arrangement [4,5]. Random dot arrangements have the advantage that they eliminate the moiré phenomenon [4] which arises when the dots have an overly regular arrangement. However, the algorithm required to generate a random dot distribution is very complicated. Various approaches have been developed to replace the conventional diffusion white spots by the carefully designed micro-features. In addition to the prismatic configuration, microlens arrays (MLA) are one of the most promising approaches for customized tailoring of the characteristics of scattering behavior. With curved contours, microlens provides built-in diffusion properties which could enhance the brightness and luminance uniformity [6].

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3.4. Optical analysis and fabrication of inkjet printing LGP

The design of a 3” LGP is investigated by utilizing an optical ray-tracing simulation tool, TracePro. The LGP is divided into eight sub-regions ([Fig. 8]). The microfeatures are lined up in columns against the light direction. The dimensions of the LGP are 84 mm × 46 mm × 0.6 mm and the microfeature used in the LGP design is a jetted dot with size of 40 μm. The optimal process parameters obtained from the afore-mentioned experiments, i.e. voltage of 12 V, distance between nozzle and substrate of 0.7 mm, polyacrylamide as ink material, as well as the set dot diameter of 20 μm were used for fabrication of LGP. A photograph of the LGP and the luminance distribution are shown in [Fig. 9(a)] and (b), respectively. The luminance values measured by nine-point test are listed in Table 2. The uniformity based on nine-point test was 83.85% with average luminous 1012.58 nit. Because the feature geometry and distribution can be accurately achieved using the proposed inkjet fabrication scheme, the optical characteristics of the LGP can be predicted with a high confidence level. Thus, design optimization of the LGP is realistic.

4. Conclusion

The effects of surface treatment, driving voltage as well as distance between nozzle and substrate on the geometrical characteristics such as shape and size of inkjet printed droplets from polyacrylamide solution on PMMA substrate were investigated in this study. The optimal jet printing voltage is 12 V and distance between nozzle and substrate is 0.7 mm. As a hydrophobic surface is applied, the formability of inkjet printed drop is improved. Then, a 3” light guide plate, designed with TracePro software, was successfully fabricated using ink-jet printing with these optimal parameters. The uniformity of the resulting LGP was 83.85% with average luminous 1012.58 nit. A complete inkjet printing microstructure molding process was established, and the inkjet printing technology proposed in this study could be extended and popularized to rapid validation of optical quality of LGPs and relevant optical industry development in the future.

References


