Microelectronic Engineering 98 (2012) 117–120

Contents lists available at SciVerse ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

Fabrication of flexible metallic wire grid polarizer using thermal NIL and lift-off processes

Chien-Li Wu, Po-Hung Yao, Chih-Hsien Lin, Cheng-Kuo Sung *, Cheng-Huan Chen

Department of Power Mechanical Engineering, National Tsing Hua University, Hsinchu 30013, Taiwan

ARTICLE INFO

Article history:
Available online 24 July 2012

Keywords:
WGP
Metallic wire grid
Thermal nanoimprint
NIL
Brightness enhancement
Lift-off
Flexible

ABSTRACT

This work is dedicated to the fabrication of metallic/dielectric double layer gratings on polymeric films for wire grid polarizer (WGP) to obtain designed optical performance as well as better process tolerance. The fabrication process was based on thermal nanoimprint and aluminum lift-off techniques. Polymeric substrates PET (Polyethylene terephthalate) and COP (Cyclo-olefin polymer) were brought into comparison for the birefringence property. At the same time, by applying RCWA (Rigorous coupled-wave analysis) simulated optical designs, it would be also capable of minimizing difficulties of ultra-precision manufacturing. Experimental results revealed that using the 240 nm pitch stacked metallic/dielectric gratings performed 192:1 extinction ratio and 1.2× brightness enhancement, which allowed larger pitch replacing the smaller pitch of WGP gratings, but still possessed similar optical performance. Hence, these designs and process configuration not only make the continuous roll-to-roll process more feasible, but also relieve the difficulties of fabricating the imprint roller stamp.

1. Introduction

Wire grid polarizer has been attracting attention to the display industry especially for the projection display applications due to its good polarization efficiency, brightness enhancement as well as wide viewing angle [1–3]. Previous research articles revealed that 50 nm half-pitch or even smaller metallic gratings were required for obtaining high contrast WGP components for the visible spectrum [4,5]. However, the corresponding processes become more challenging because of the required fine pitch, especially, for large areas and flexible substrates. This may not be a major difficulty for conventional WGP fabrication processes, since they are usually performed on rigid substrates such as glass or fused silica [3–5]; those substrates are more compatible to the well-developed semiconductor process (e.g., photo lithography, thin-film deposition and etching).

WGP component mainly contains a series of parallel metallic gratings (the conductive layer) that are deposited on the dielectric substrate or structures [3,6,7]. To obtain wide selectivity of conductive materials, lift-off process was adopted in this study not only for its physical metal deposition process that would be easy to change to the alternative materials. Moreover, by selecting the appropriate solvent soluble imprint resist, it even made the fabrication process more efficient compared with the metal etching process. These process platform and optical design make the continuous roll-to-roll (R2R) process even more feasible, and also relieve the very low process tolerance resulted from the small critical dimensions of gratings [8].

2. Experimental setup

In the present work, we demonstrate that double-layer gratings containing parallel stacked aluminum and dielectric layers could be fabricated efficiently using thermal NIL and lift-off process for the applications of wire grid polarizer as well as brightness enhancement films. The solvent soluble thermoplastic NIL resist (mr-I 8020R, Micro Resist Technology) was applied in this study. Thick resist (150 nm) was spin coated on polymeric substrates (PET and COP) and followed by 3 MPa thermal NIL at 150 °C with 60 s of pressure holding time. The optical properties of PET after thermal NIL were inspected using the spectrometer. Herein, less than 2% transmittance variation was obtained, which means the short thermal NIL periods did not damage the optical properties of PET. The dimensions of the imprint stamp made by laser interference lithography were 310 nm in depth, 240 nm in pitch, and 110 nm in line width; the size was 3 × 3 cm^2. The polymeric substrates of optical-grade PET (A4300 125 μm, Toyobo Co.) and COP (ZeonorFilm ZF16-100, Zeon Co.) films were chosen as the replacement for the rigid substrate shown in the previous work [3–5], which could provide more flexibility and even suitable for continuous R2R process.

The reasons of using COP film were its low birefringence property, good thermal and chemical resistance [9]. By selecting low

* Corresponding author. Tel.: +886 3 574 2918; fax: +886 3 571 5314.
E-mail address: cksung@pme.nthu.edu.tw (C.-K. Sung).

0167-9317/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.mee.2012.07.081

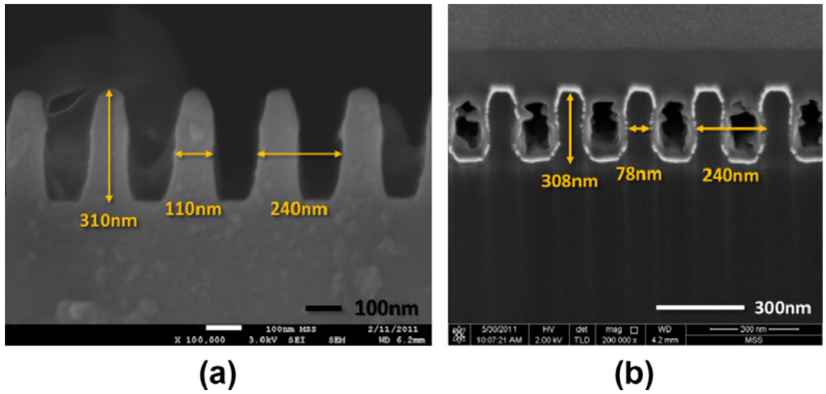

Fig. 1. (a) Silicon NIL stamp. (b) Cross-sectional view of thermal imprinted resist gratings on PET substrate.

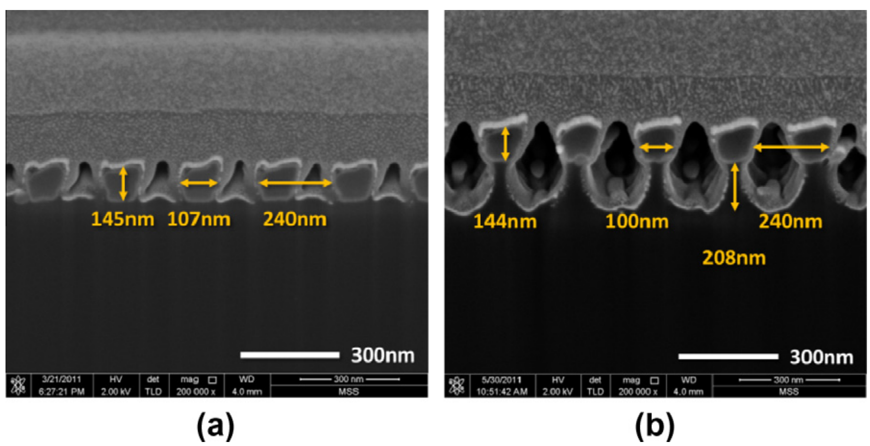

Fig. 2. (a) Cross-sectional SEM image shows 145 nm height aluminum gratings deposited on PET substrate after lift-off process. (b) PET anisotropic etching by argon plasma.

retardation polymeric COP films, WGP components are more appropriate for replacing the rear polarizer embedded in the LCD (liquid panel display) panel when the pre-polarizer film, for instance, DBEF (dual brightness enhancement film), is already adopted. This kind of low retardation material will not diminish the polarization efficiency of the LCD panel, which should be firstly concerned in the WGP fabrication process. Besides, TAC (triacetyl cellulose) and PMMA (polymethyl methacrylate) films that are widely used in the display industry are not suitable for the lift-off process when using solvents such as acetone; this kind of substrate will be damaged during the wet chemical process and the optical quality will be no longer acceptable. Herein, COP films provided adequate performances for WGP substrates in the experiments.

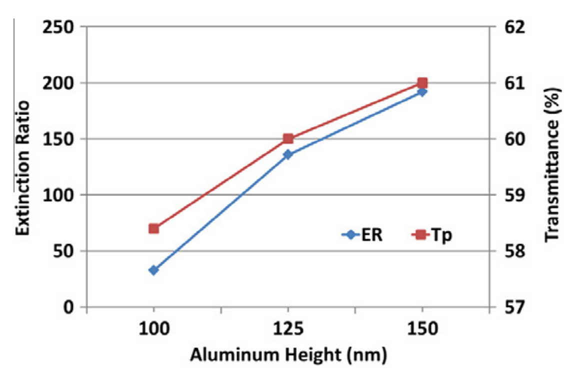

Fig. 3. Optical performance with respect to the height of aluminum gratings at the wavelength of 635 nm.

3. Results and discussion

For the NIL process, zero RLT (Residual layer thickness) was achievable; however, concerning the large-area imprint uniformity, 5 s argon plasma etching (300 W power, flow rate 65 sccm) was utilized to make sure the residual layer was completely removed. Aluminum was thermally evaporated onto the resist structures after removing the imprint residual layer. Fig. 1 shows the silicon stamp and resist structures patterned by thermal NIL. The final height and width of the resist gratings were 308 nm and 78 nm, respectively. Fig. 2a shows the 145 nm height aluminum gratings deposited on the PET substrate using lift-off process with 10 s acetone soak and ultrasonic agitation, which shows more efficiency than the conventional aluminum etching technique. Smoother aluminum gratings could be obtained by using better quality (e.g., sidewall angle and surface roughness) NIL stamps and fine-tuned aluminum deposition process.

To enhance the extinction ratio and the transmittance, argon plasma was applied again to etch the dielectric layer (PET or COP substrates) to approximately 208 nm in depth as shown in Fig. 2b. The reason for using argon plasma was to prevent the deposited aluminum to be further oxidation, even though the firm native aluminum oxide existing on the surface could also eliminate the oxidation issue in the case of plasma etching. The etching depth of the dielectric layer was simulated and optimized using RCWA according to the fabricated aluminum gratings. Similar