Preparation of Patternable High Resolution and High Refractive Index Materials for AR/VR

Jiro Hikida, Hiroki Chisaka, Yoichiro Ijima, Yuehchun Liao, Kenri Konno, Isao Hirano, Kouichi Misumi, Dai Shiota, Katsumi Ohmori

j-hikida@tok.co.jp,
Tokyo Ohka Kogyo Co., Ltd., 1590 Tabata, Samukawa-machi, Koza-gun, Kanagawa, 253-0114, Japan

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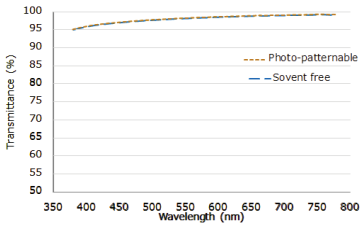
ABSTRACT

The patternable materials have been improved to be high transparency, high resolution, and adaptable for patterning with photolithography, ink-jet print and imprint. Moreover, combination of high refractive index materials and the patternable technologies led to wider applications for next generation of display industry, such as AR/VR and smart glasses

1 INTRODUCTION

In recent years, high refractive index (HRI) materials are used to improve the performance of display panel, for example, light extraction in OLEDs is only 20% or less since OLED is an optically isotropic material. Compared to LCD, it is necessary to increase the light extraction efficiency and the orientation of light. This can be achieved using a high refractive index material to reduce the amount of light trapped due to index mis-match between device layers. [1][2][3] In order to achieve both material requirements of high flexibility and HRI, HRI filler is generally used. In our previous work, the photo-patternable type and solvent free type HRI material were developed by the combination of the HRI filler with small particle size and TOK photoresist technology. [4] In order to extend applications of the HRI materials, TOK developed a variety of HRI materials for photolithography and inkjet print process which have superior transparency (Fig. 1) and pattern resolution. [5] In this work, we continuous improve RI> 1.70 with modification of TOK HRI materials for photolithography and inkjet print process, and also developed a new HRI material for imprint lithography process with RI=1.85 (at 530 nm). TOK has been studied and developed the imprint material for long time, and a pattern formation technology to imprint a fluid resist material with a patterning mold was developed.[6] Due to UV imprint lithography precisely enables complicated pattern formation on large square substrates at once. [7]

On the other hand, high refractive index micro patterns have been focused on applications to optical materials such as diffractive optical elements (DOE) and micro lenses [8][9]. Multi-level structures as SEM image are essential for DOE fabrication. [8] (Fig. 2). Those imprint resist materials are mainly composed of both a binder resin as a photo-curable liquid polymer and metal oxide nanocrystals as HRI fillers. Although RI of imprint resist materials could be improved by adding HRI fillers, but it would be too hard to be imprinted with patterning molds due to the lack of their fluidity. In other words, there is a trade-off between RI and the fluidity of material. The fluidity of HRI imprint material acts a key role to the pattern formation. Therefore, TOK optimized the ratio of resin binder and HRI filler to control both the material fluidity and RI to develop, HRI-211, a HRI material consists of HRI fillers and Polyacrylate for imprint lithography process.



T%@λ	HRI materials	
	Photo-pattern [FT=3 um]	Solvent free [FT=10um]
400 nm	96.2	96.0
500 nm	97.7	97.7
600 nm	98.6	98.5
700 nm	98.9	98.9

Figure 1 Transmittance of TOK HRI materials. Photo-patternable (Blue); Solvent free/ink-jet (Brown)

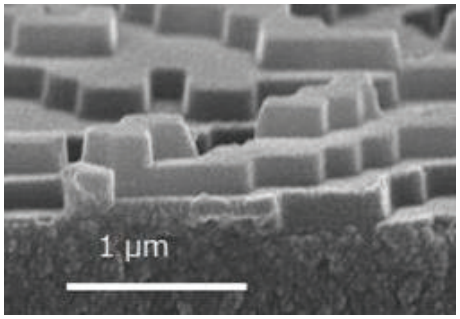


Figure 2 SEM image of a multi-layer nanostructure.

2 EXPERIMENT

2.1 Photolithography test

Photo patternable type HRI material was formulated and then spin-coated onto Si wafer. Exposure executed with i-line stepper (Nikon). After development by 2.38 % TMAH aq., pattern was observed using FE-SEM. (Fig. 3).

2.2 Inkjet test

Solvent free type HRI materials was formulated and then discharged onto glass substrate by inkjet tool. The formed film properties were checked as same as photo patternable film. (Fig. 3)

2.3 Imprint test

HRI-211 was prepared by blending colloidal Titania (TiO2) nanocrystal with Polyacrylate and photo radical initiator in PGMEA, and then spin-coated onto a Si substrate. The coated film was heated on a hot plate at 100 oC for 2 min and it was imprinted with a 70 nm 1:1 line-and-space patterning mold at 0.5MPa of imprint pressure and photo-cured by 365 nm UV irradiation of 1 mJ/cm2. (Fig. 3) Line patterns of HRI-211 were observed by FE-SEM.

2.4 Optical property measurement

RI of films was measured by a spectroscopic ellipsometer.

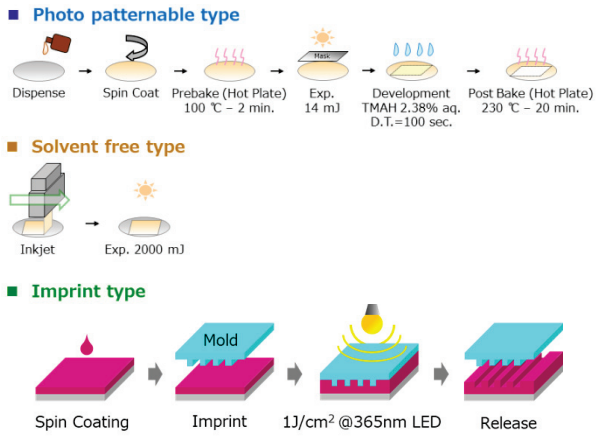


Figure 3 Process flows of TOK HRI materials.

3 RESULTS

3.1 RI

The RI numbers of films were achieved 1.67~1.85 controlled by TOK with a variety of HRI material formulations. The RI of HRI-211 was achieved 1.81 at 530 nm, 1.80 at 589 nm and 1.76 at 940 nm, respectively. (Fig. 4)

3.2 Resolution

The film of photo patternable type HRI material was prepared with process as shown in Figure 3. The CD was achieved as 2.4 µm with mask CD 1.8 µm. (Fig. 5)

The steep 70 nm line patterns of HRI-211 are arrayed at the depth of 70 nm between two lines, (Fig. 6) which the patterning ability as good as HRI filler free material.

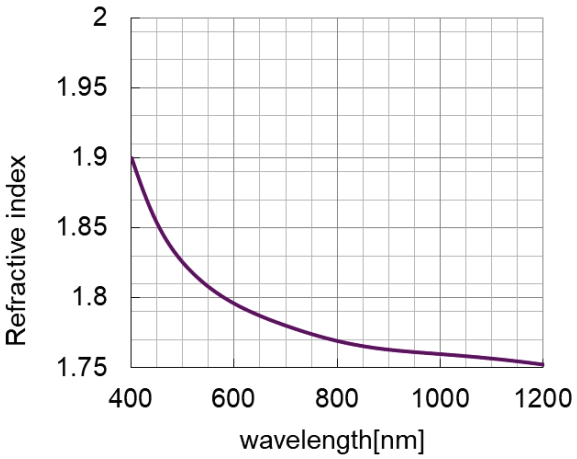


Figure 4 Refractive index of HRI-211.

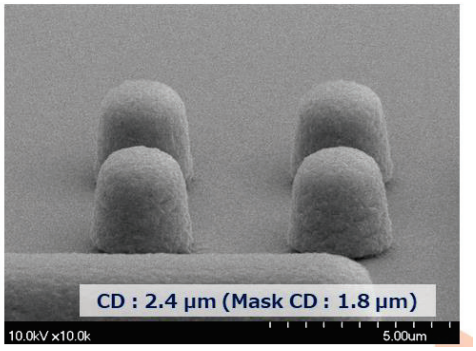


Figure 5 Resolution of TOK Photo-patternable HRI material.

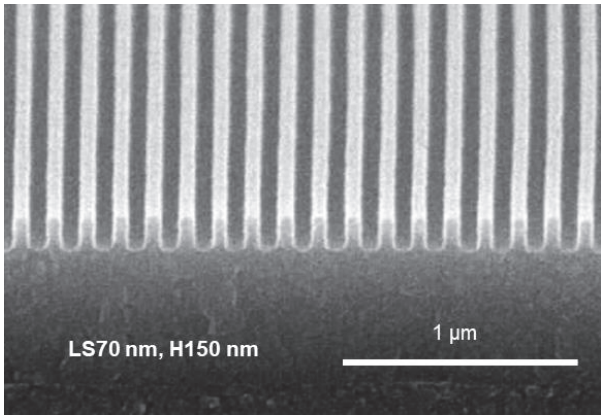


Figure 6 Line patterns of imprinting HRI material

(Type : HRI-211 NL)

4 CONCLUSIONS

In this study, HRI materials consisted of patternable resists and HRI fillers were developed. The materials have not only high transparency, but also high RI, high resolution and durability have been improved. TOK is continuously developing a variety of HRI materials for photolithography, inkjet and imprint lithography which also targeting for wider applications such as requirements of AR/VR.

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