Study on induced strain in slanted grating during mold releasing process

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Introduction

Light and thin smart glasses for virtual reality (VR) or augmented reality (AR) are indispensable for metaverse devices. One of the promising approaches is use of slanted gratings to propagate vertical images into human eyes through thin glass. There have been developed with thin-film reflective/transmissive mirrors by a diffraction grating with a slanted grating structure containing TiO2 nanoparticles with a large refractive index [1]. Nanoimprinting has been used in some cases as a fabrication method for such optical structures, but one of the important processes is the release process of the slanted structures [2].

In this work, we discuss the induced strain caused by the release process of the slanted structure using numerical simulation and compared to experimental study.

Numerical simulation

For the mold release process, the mechanism has been clarified based on a fracture mechanics model [3] and verified with experiments [4].

We estimate induced strain during releasing process by numerical simulation. The grating structure are slanted 60 degrees. The mold is peeled at the both ends and the ratio of the elasticity modulus E_m and E_r are considered. Figure 1 (a) shows the schematics of the peel releasing model. Both ends of the mold are vertically pulled up where the lateral displacement was free.

Results and discussion

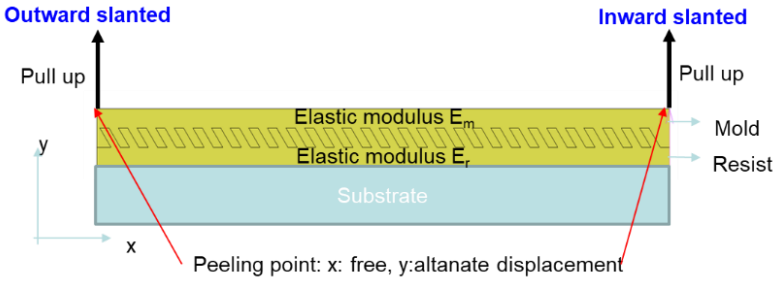
Figure 1 (b) shows the induces strain by peeling. In the case of toward slanted direction (Outward slanted direction), the mold and resist pattern face each other in opposite directions (Inward slanted direction). Therefore, when the mold pattern is lifted up to the top of the resist, a large strain over 100% is induced.

On the other hand, induced strain decreases in the separation model for toward slanted direction, but increased for opposite directions. This fact was confirmed by experimental study.

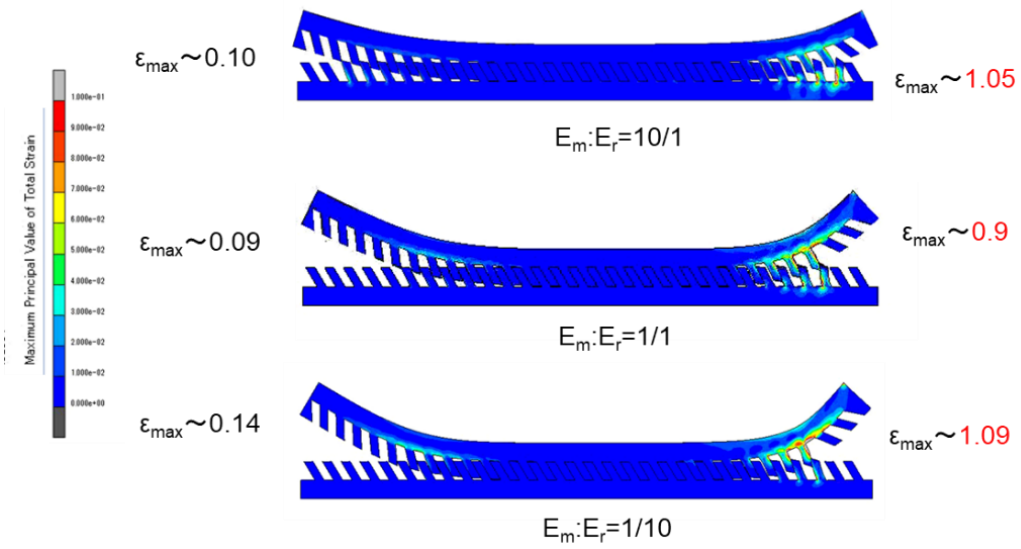
To investigate the flexural rigidity of the mold, upper layer was added on the mold as illustrated in Fig.2 (a) to extend the rigidly about 100 times. As shown in Fig. 2 (b), the induced strain could be suppressed below 0.5 because This is because the mold pattern is less likely to be curved during mold release, and the resist pattern is less likely to bend in the opposite direction and move toward vertical direction for inward slanted structure. However, the induced strain increase for outward slanted structure.

References:

[1] For example: A. Alexeev, et al.; Abstract of NNT 2019 (2019, Boston).
[2] G. Calafiore; 64th EIPBN (2021, Virtual) 2C-1.
[3] T. Shiotsu, et al.; *J. Vac. Sci. Technol* B, **31** (2013) 06FB07.
[4] T. Tochino, et al.; *Jpn. J. Appl. Phys*. **54** (2015) 06FM06.

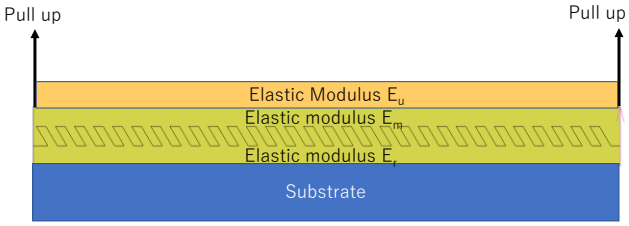


(a) Peeling model for slanted grating



(b) Induced strain

Fig. 1. Peel mode for slanted grating.



(a) Schematics of push-pull separation model for slanted grating

ε_{max}~0.26 ε_{max}~0.49

E_m / E_r / E_x=1/1/100

(b) Induced strain

Fig. 2. Separation mode for slanted grating.