Development of Functional Transcript Resin Sheets for Nanoimprint Applications

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1. Introduction

Nanoimprint technology is a surface microfabrication technology that develops the well known emboss technology in the optical disk production, and improves the resolution up to the nano order size [1-3]. Recently, the nanoimprint technology attracts attention as one of the methods of product micro indentation as the existing injection technology is unfeasible for mass production could be mass-produced in the semiconductor field, the display field, and the optical material field, etc.

Mold and the transcript material are necessary in the nanoimprint material. In recent years even though the development of the transcript material is advanced in various fields, however, when the mastering molding made by the lithography method is used directly, it becomes a problem in respect of the cost and throughput [4]. Moreover, making the replica mold by making the nickel material has problems such as maintenance of shape in plating wet process, damage of mastering mold when mastering mold is separated from nickel and reversing of shape. Therefore, molding made of HSQ is proposed. [5-6].

Our company is paying attention to the thermal nano imprint method with the advantage of wide coverage of the material for several years in each method compared with other methods like the abundance of the mold material and the transcript material, and is developing the functionality transcript resin and the application for the nano imprint that can be applied optics and the telecommunications sector [7-8].

This study reports on the result of the resin that can maintain surface minute shape in a wet process such as the metal plating and the nickel

replica mold as one of the applications of the functional resin with a promising better nanoimprint transcript.

2. Experimental

2.1 Transfer Condition of Nano Structure Using Functional Transcript Resin

The thermal nanoimprint process is shown in Figure 1. In this examination, the new resin A and the PMMA resin of Mw=1,000,000 developed was used and examined. First, the resin was to be coated on a glass substrate approximately 1 μm in the film thickness as for the resin. Next,

1. Coating

2. Heating Resin and Press Mold

3. Mold Remove

Fig 1. Schematic of the thermal imprint process

thermal nanoimprint was done by using the L&S molding of 150 nm width made of quartz, 300 nm period and aspect ratio 1 as quartz mold, and Toshiba Machine ST-50 as a device under following prescribed condition. The thermal imprint was done on the condition of 10 MPa load, 130 °C transcript temperature, 90 °C remove mold temperature, and 5 minutes transcript time. The transcribed object is used for the subsequent UV cured PMMA. Moreover, nanoimprint was prepared and used in the study for comparison.

2.2 Fabrication of Electroforming Process

The electroforming process consists of metal plating process with the electric conductive layer formation. The electric conductive layer of the 10 nm thickness film was processed from the number on the nano pattern as described in section 2.1 using the sputtering method. Afterwards, the pattern was formed with the electroforming process. The metal plating process was done for 2-3 hours on the nickel sulfamine based solution with a pH value in range of 5.0, and 50 °C temperature. After the metal plating process, the resin was dissolved in the acetone, and nickel was detached. Finally, it was resolved by processing

1. Conducting Process

2. Electroforming

3. Dissolving Resin

4. Cleaning (Ashing)

Fig 2. Schematic of the electroforming process

the remaining resin on the nickel surface by ashing process.

2.3 Thermal Nanoimprint Condition Using Nickel Replica Mold

The thermal nanoimprint was performed using the nickel mold as described in section 2.2. The new resin A and the PMMA resin of Mw=1,000,000 were used as the transcript resin, and examined on the condition of 10 MPa load, 130 °C transcript temperature, 90 °C remove mold temperature, and 10 minutes transcript time. Moreover, nanoimprinted UV cured PMMA prepared and used for comparison in the following examinations.

2.4 Measurement

As nickel is a magnetic substance, precision measurement cannot be done with normal scanning electron microscope (SEM). Therefore, the width and the period were measured with out type lens SEM. Moreover, three dimension surface roughness devices are used for defect inspection, and the depth measurement was done by using atomic force microscope (AFM).

3. Results and Discussion

3.1 Results of Nanoimprint Process Using The New Transcript Resin

Table 1. Pattern dimension of mold and transcript resin plate

	Quartz Master Mold	Transcript Resin Plate	Nickel Mold
Period (nm)	300	299	299
Depth (nm)	135	135	134

Fig 3. SEM micrograph of new resin A after the nanoimprint.

Table 1 and Figure 3 shows the result of shape

measurement of the transcript resin after the imprint. When the nanoimprint was done by using the new resin, the stroke width and the depth of the pattern after imprint were the same as the value of the stroke width and depth of the master mold by the measurement that used SEM and AFM. In comparison, PMMA and UV curing type PMMA were similarly shows excellent transcript accuracy.

3.2 Results of Electroforming Process

Note that the nickel replica mold is made by using the resin are described. First, there is neither shrinkage nor an expansion of the resin, and the signal shape is kept in a wet process of the nickel plating. Moreover, neither breakdown of the pattern type nor the tension of the nickel plating was found when the transcript resin plate is detached from the nickel plating after the metal plating process.

Figure 4 shows the result of nickel mold after the metal plating process. Neither crack nor peeling off was generated in the nickel mold made with new resin A in the metal plating process. Moreover, both the resin and the nickel were able to be separated easily by infiltrating the acetone, and dissolving the resin. On the other hand, the PMMA resin shrank in the metal plating process shown in figure 4 the whole surface cracked and the base material of the resin peeled off from the substrate. For comparison, only few cracked was found on UV cured PMMA.

A typical result of SEM and AFM of the nickel mold for is shown in Figure 5. The nanoimprint shape is especially maintained in the metal plating process from these results, and it was suggested that the replica accuracy be also very high. It is because new resins A have both functions of the excellent construction in nanoimprint process and

selectivity of dissolution to solvents as the reason why the replica in high accuracy was able to be made. On the other hand, the proof plating is low, and the crack enters in the metal plating process when general PMMA is used. The UV or thermal curing resin doesn't dissolve to the solvent, the shape part of the nickel is damaged, and it distorts when resin and nickel are separated.

The nanoimprint to PMMA was carried out by using the nickel mold to confirm whether the produced mold was able to be used for the nanoimprint process. When the pattern was printed by using the nickel mold, the release agent that is appropriate for the nickel mold was

(A)

(B)

Fig 5. (A) SEM micrograph and (b) AFM image of nickel mold after the electroforming

a) New resin

b) PMMA

Fig.4 Optical photomicrograph ($\times 5$) of a) new resin and b) PMMA

processed, and imprint was done afterwards on the same condition as the condition to use the quartz master mold.

Next, the feature of the production technique of the examined replica mold process is described here in the application of the functional resin the focus.

There are three advantages in producing to the replica mold through the resin as shown in Figure 6. First of all, the same shape of the master mold can be made a replica (shape does not reverse). Next, the mastering molding is not destroyed. Finally, two or more replicas can be facilitated.

The result of ten pieces of nickel molds made at a time by the nanoimprint using a new resin and the metal plating process is shown in Figure.7. The size reproducibility in the nanoimprint and the metal plating process was very high, and the replica was made without destroying the mastering molding. The result was suggested that this method was effective for making the replica molds, two or more pieces.

4. Conclusion

The transcript material that uses new resin A has reported the following advantages.

1. Good nanoimprint transcript accuracy.
2. No shape change in the metal plating process.
3. Simple separation after metal plating is processed.

The application to various wet processes will be examined by using the new resin A in later stage.

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Fig 6. Schematic of the replica mold process

Fig 7. Pattern pitch and depth of nickel replica molds