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Large size nano-patterned nickel roll mold fabricated using nanoimprint and elelctroplating process

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Abstract

Roll to Roll (R2R) process[1] is one of the mass production technology usually to fabricate film products. The most important component in the R2R process is a cylindrical mold. The cylindrical mold has a variety of patterns on it and it is fabricated by machining and electroplating process. Recently, a special film product which has nano-pattern on it draws interests from R2R process researchers and a lot of effort is being put into making a nano-patterned roll. The roll mold usually has longer than 300mm length and bigger than 200mm diameter. However, it is not easy to fabricate nano pattern directly on the whole surface of a roll mold. So, we studied an indirect method which composed of a flat metal mold fabrication step and a roll-winding step which winds and fixes the flat mold on a cylindrical roll body. In the first step, we use nanoimprint process to make a large flat nano-pattened film. A polydimethylsiloxane(PDMS) stamp is replicated from a master silicon wafer which has 300nm hole patterns and a polyurethane acrylate(PUA) resin is used in nanoimprinting process[2-4]. The unit patterning area with this PDMS replica is 110mm by 110mm and the patterning area is enlarged by a home-made roll-nanoimprinting tool. The size of the final patterned film is 600mm and 110mm and it is electroplated to make a nickel metal sheet. This sheet is copied several times and welded each other to make one large nickel sheet. We electroplated this nickel sheet one more time and made one 600mm x 600mm size nano-patterned nickel sheet. To make a final roll mold for R2R process, we wound it on a 600mm in length and 200mm in diameter cylindrical body.

roll-to-roll process, nanoimprint, electroplate, roll mold

1. Introduction

Many researchers are looking forward that nano-patterned products will give revolutionary effects on many engineering fields. However, the cost and throughput will be the key parameters whether the nano-patterned products are commercialized or not.

We believe the R2R process is the only solution to commercialize the nano-patterned items and many researches related to the R2R technologies are carried out. The key component is a roll mold which has a pattern to be transferred on a film. Nowadays, the R2R process are focusing on micro-patterend products, for example RFID sensors, anti-counterfeiting patterns, and bio sensors. However, for nano patterned products, the fabrication process of a roll mold should be changed dramatically to satisfy cost-of-ownership.

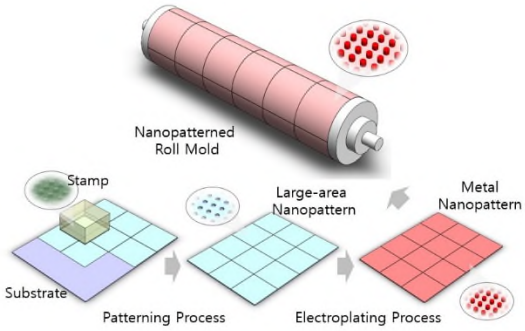

Figure 1. The concept drawing how to make metal roll mold.

Although the E-beam lithography is widely used to fabricate a seamless roll mold, it has disadvantages like a very long fabricaton time and weak strength of the final patterned polymer layer like ZEP520A[1-2].

Figure 1 shows the concept fabrication steps we proposed in this paper. Instead of fabricating nano-patterns directly on a cylindrical surface of a roll mold, we make a flat nano-patterned mold first, then wind it on a cylindrical body to make roll mold for R2R process[3]. Of course, this scheme is not perfect, especially the seam lines between the edges of the wound flat sheet is not eliminated. However, this method is very economical because the flat sheet can be copied easily by electroplating process, so if the roll mold is damaged or contaminated we can replace it by a new roll mold quickly.

2. Roll nanoimprint tool

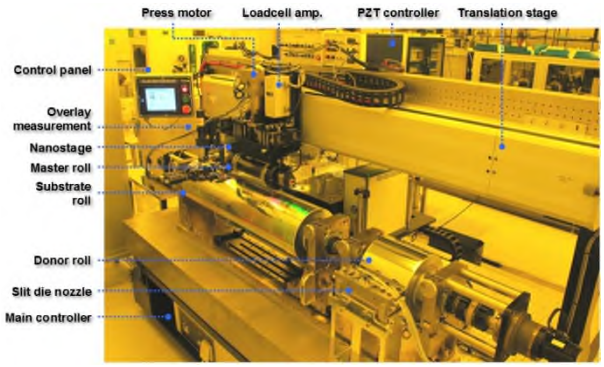

Figure 2. Roll nanoimprint tool

Figure 2 shows the roll nanoimprint tool we used[4-6]. This machine is used to enlarge the nano-patterned area by stitching process. A PDMS replica which copies a mater pattern from a silicon wafer is attached on the master roll moving along the translation stage. A polycarbonate(PC) film is placed on the substrate roll which is located beneath of the master roll. Another PC film which is coated by PUA resin is placed on the donor roll, and then the PDMS replica transfers the PUA resin from the donor roll to the substrate roll similar to transfer printing. The pattern area of the PDMS is 110mm x 110mm and hole or dot patterns whose size is 300nm in diameter are used in this experiment.

3. Experimental results

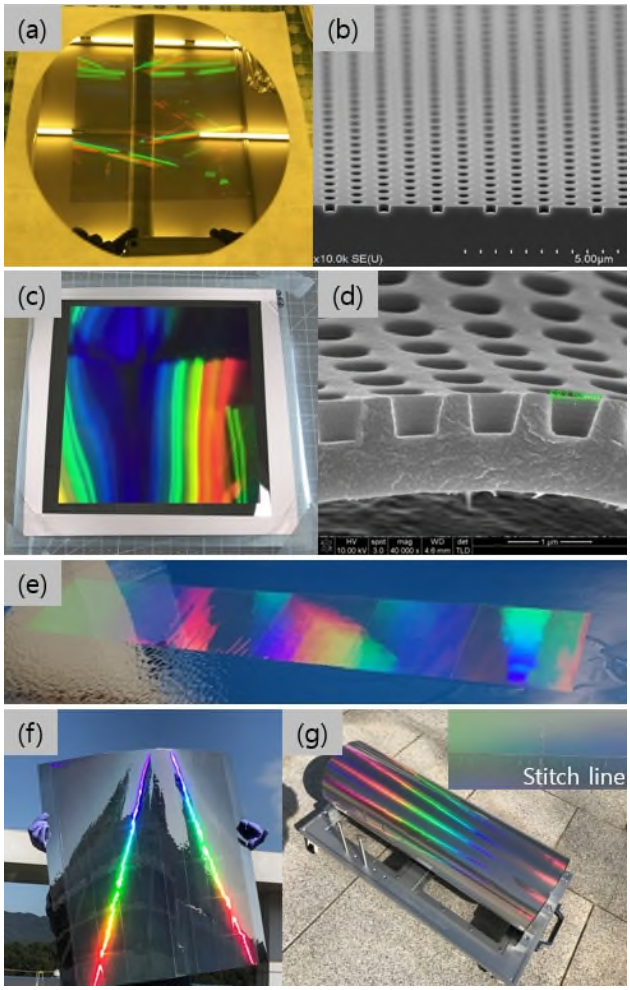

Figure 3. The whole process to make a nano-patterned nickel roll mold; (a), (b) 8-inch size silicon master which has 300nm size hole pattern and its area is 110mm x 110mm. (c), (d) a nickel flat mold which is electroplated from a nano imprinted film. (e) 1x6 size nickel flat mold. 110mm x 600mm. (f) 600mm x 600mm size nickel flat mold. (g) final roll mold in 600mm in length and 200mm in diameter and the stitch lines between each 110mm x 110mm nanoimprinted regions.

Figure 3 shows the whole process how to make a nickel roll mold. Figure 3 (a), (b) show the silicon master wafer and its hole pattern. This master is fabricated by E-beam process. Figure (c), (d) show the nickel flat mold and its pattern electroplated from a PUA nanoimprinted film using the tool shown in figure 2. The hole pattern size is wider than the size of the original one, because of a copper seed layer deposited on the PUA layer for the electroplating process. Figure 3 (e) shows a large size nickel sheet. First we roll-nanoimprint PUA resin on a PC film, so the 110mm x110mm unit area is enlarged to almost 110mm x 600mm size. The copper seed layer is deposited on the PUA film, then electroplating process is proceeded. After peeling off the PUA film, we can get a nano-patterned nickel flat mold. This one stripe of nickel mold is copied 6 times, and then these molds are welded together. This coalesced nickel mold is electroplated again to get 600mm x 600mm size nickel mold. Figure 3 (f) shows the final large size nickel mold, and the rainbow stripes show the existenance of nano pattern which has 300nm in diameter and 1um in pitch. This flat mold is wound on a cylindrical roll body, and fixed by bolting shown in figure 3 (g).

In future, we plan to apply this nickel mold to the R2R process. Through this experiment, we expect to upgrade this nickel mold with further improved adhesion, wear and contamination.

4. Conclusions

We proposed a new scheme to fabricate a nano-patterned roll mold by winding a flat mold. We also use roll-nanoimprint process to enlarge the PUA patterned area. Ideally, the stitching lines between nanoimprinted regions should be eliminated using proper resin dispensing. However, imperfection of the edges of a PDMS replica and the nonuniformity of pressure give thick stitching lines shown in the small picture in figure 3 (g) . Further researches are needed to make these stitching lines invisible. The discontinuity at the seam line is inevitable, but we believe this method is very economical.

Acknowledgements

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References

[1] Ojima K, Saito M, Unno N, and Taniguchi J, 2016 J. adv. Mech. Design, Sysem, and Manufacturing 10(5) 1-5
[2] Tseng S C, Peng W Y, Hsieh Y F, Lee P J, and Lai W L, 2010 Microelectron. Eng. 87, 943-946
[3] Lim H J, Choi K B, Kim G H, Lee S H, Park H H, Ryu J Y, Jung S H, and Lee J J 2014 Microelectron. Eng. 123 18-22
[4] Chou S Y, Krauss P R, and Renstrom P J 1996 J. Vac. Sci. Technol. B 14(6) 4129-4133
[5] Kim G, Park H, Joo J, Jang K, Kwack M, Kim S, Kim I, Oh J, Kim S, Park J, and Kim S 2015 Sci. Rep. **5** 11329
[6] Ji R, Hornung M, Verschuuren M A, van de Laar R, van Eekelen J, Plachetka U, Moeller M, and Moormann C 2010 Microelectron. Eng. 87 963-967