Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.840-841

P11-10L

Fabrication of Photonic Crystals Using Nanoimprint Lithography

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Abstract

Two-dimensional polymer photonic crystals using the nanoimprint lithography technology have been developed. The polymer photonic crystals with two-dimensional holes and pillars were obtained by the positive and negative silicon molds, respectively. The imprinting conditions including temperature, pressure, and time were used to control the resulted patterns of the polymer photonic crystals.

1. Introduction

Photonic crystals [1-2] have periodic structures with different dielectric properties so that the refractive indices vary periodically in space. The resulting Bragg scattering of electromagnetic waves in the photonic crystals leads to formation of photonic bandgaps where the propagation of the electromagnetic waves in certain frequency bands are forbidden.

Nanoimprint lithography [3] with advantages of low cost and high throughput is a promising technology to fabricate nano-structures. It has been included in the international technology roadmap for semiconductors (ITRS) for next generation lithography technology. The nanoimprint technology has great potential for applications of photonics.

In this paper, we demonstrate two-dimensional polymer photonic crystals using the nanoimprint lithography technology. The polymer photonic bandgap devices with different geometric dimensions and structures have been fabricated

2. Experimental Results and Discussion

The fabrication procedure of the polymer photonic crystals using the nanoimprint lithography is shown in Fig. 1. The molds for imprinting were made of silicon wafers. The molds were patterned by resists and etched by an electron cyclotron resonance (ECR) dry etcher. Both the positive and negative molds were fabricated. The positive molds have elevated features on a large recessed surface. The negative molds have recessed patterns within a large elevated surface. An anti-sticking fluorocarbon film was coated on each mold prior to imprinting to avoid the adhesion problem of the nanoimprint.

Silicon wafers were adopted as the substrates of the polymer photonic crystals. After cleaning the silicon wafers by the standard RCA clean process, thermal-plastic polymer materials were coated on the wafers. The substrates with the polymer films were baked in an oven at a temperature of 90 °C for 30 min for solvent removal.

During the imprinting process, the chamber of the nanoimprint equipment was heated at a temperature higher than the glass transition temperature of the polymer so that the polymer behaves as a viscoelastic flow. The imprinting pressure was kept at 380 psi. The mold was pressed into the polymer on the substrate for pattern replication. Until chamber was cooled down to the room temperature, the pressure was released and the mold was then removed from the polymer.

Fig. 2 shows the structures of polymer photonic crystals obtained from the nanoimprint lithography with the positive and negative molds. The fabricated molds and polymer photonic crystals were observed by scanning electron microscopy (SEM). The positive and negative silicon molds fabricated are shown in Fig. 3. The fabricated two-dimensional polymer photonic crystals are shown in Fig. 4. The polymer photonic crystals with two-dimensional holes were resulted from the positive molds. The polymer photonic crystals with two-dimensional pillars were made by the negative molds. The sizes of holes and pillars were determined not only by the dimensions of molds but also by the conditions of imprinting. The polymer photonic bandgap devices have been successfully achieved.

3. Conclusions

We have developed two-dimensional polymer photonic crystals by the nanoimprint lithography technology. Both the positive and negative silicon molds have been fabricated. The elevated features on the positive molds generate periodic air holes in the polymer. The recessed patterns on the negative molds result in polymer pillar arrays. The patterns on the mold were transferred to the polymer at the temperature higher than the grass transition temperature. The photonic bandgap devices have been fabricated under different imprinting conditions using the low-cost mass-manufacturing nanoimprint technology.

Acknowledgements

This work was supported in part by the National Science Council of the Republic of China under Contracts NSC 91-2218-E-018-001, NSC 92-2218-E-018-001, and NSC 93-2215-E-018-001.

References

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[2] S. John, Phys. Rev. Lett. **58** (1987) 2486.
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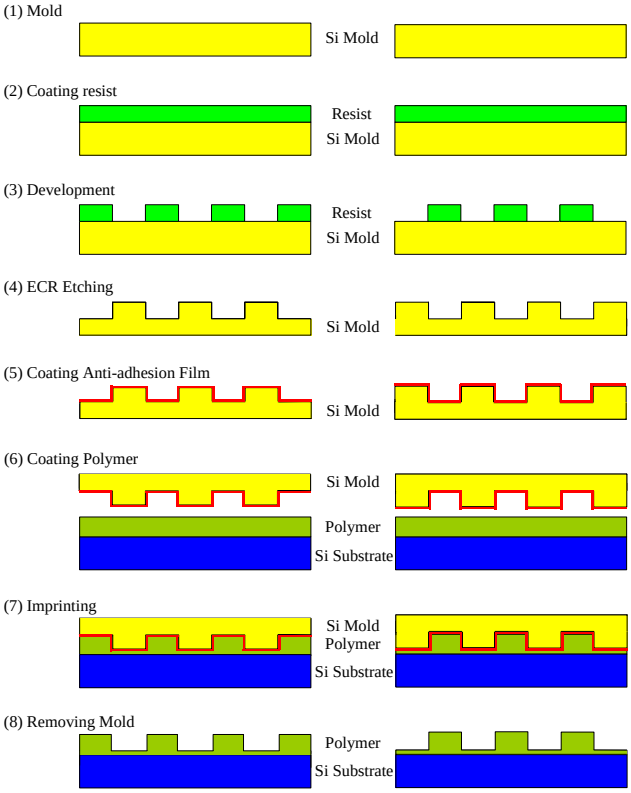
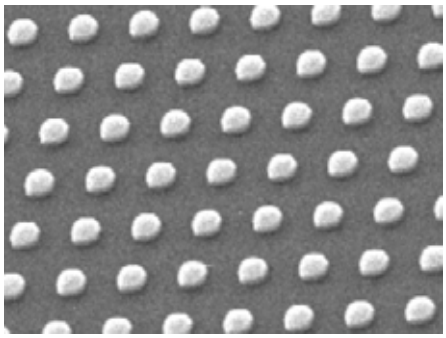
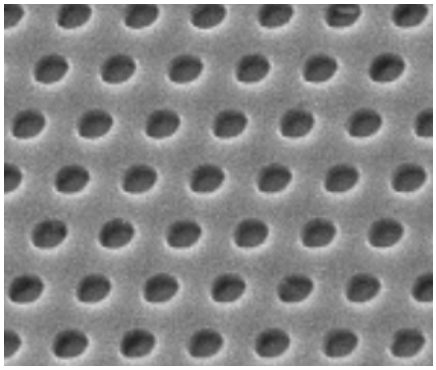


(a) (b)

Fig. 1. Fabrication procedure of two-dimensional polymer photonic crystals using nanoimprint lithography with (a) a positive mold and (b) a negative mold.

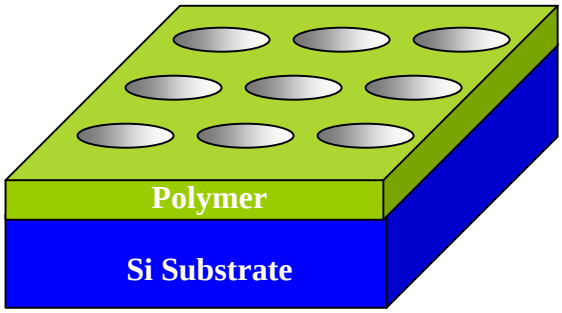


(a)

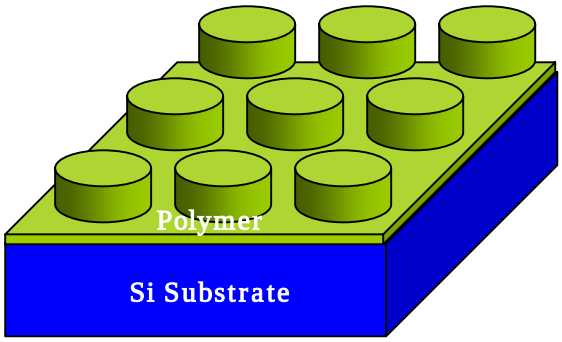


(b)

Fig. 3. Fabricated silicon molds. (a) Positive mold. (b)Negative mold.

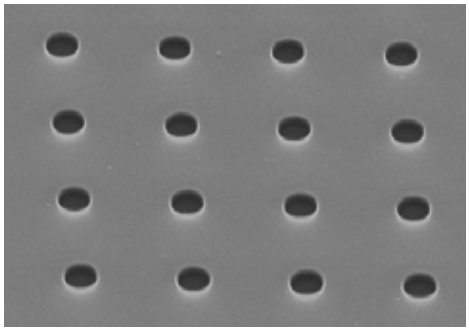


(a)

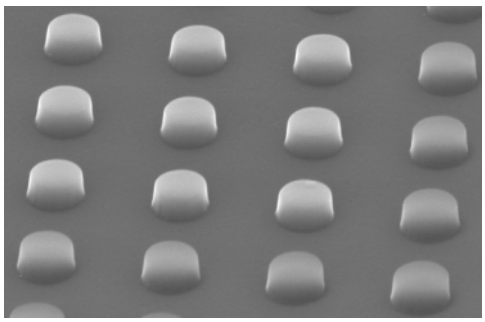


(b)

Fig. 2. Structures of polymer photonic crystals obtained from nanoimprint lithography with (a) a positive mold and (b) a negative mold.



(a)



(b)

Fig. 4. Fabricated two-dimensional polymer photonic crystals. using nanoimprint lithography with (a) a positive mold and (b) a negative mold.