Novel PDMS/epoxy stamp for imprint lithography

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Abstract

Polyurethaneacrylate (PUA) stamp has been used for the pattern formation on the dielectric layer, but the transferred patterns have some defects due to the high modulus of the stamp. To overcome these problems, polydimethylsioxane (PDMS) stamp was used as an alternative whose modulus was controlled by the epoxy contents. The PDMS stamp was fabricated from 4”silicon master with no defect, and was used for the pattern formation on the dielectric layer. The patterns on the dielectric layer were checked with scanning electron microscope (SEM), and confocal microscope, and there was no defect on the layer.

Keywords: imprint lithography, PDMS stamp, modulus, surface modification

1. Introduction

UV lithography is a conventional pattern formation method, and fine pattern below 60nm can be fabricated with this method. This patterning method is used in the industrial area due to the reproducibility. But, it has some shortcomings like high production cost, and pattern formation on the curved surface. Therefore, non-conventional lithography methods have been devised to make high resolution pattern with low cost. (Fig. 1)

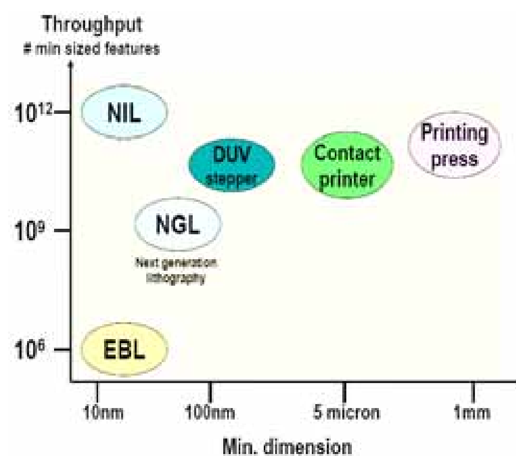


Fig 1. Non-conventional lithography method, and their resolution limits.

Nano imprint lithography (NIL) is devised by professor Stephen Y. Chou at early 90’s, and is an improved patterning method of hot embossing method which was used for the fabrication of large pattern above several hundreds micrometer. Stamp having high resolution pattern is pressed with heat or UV on imprintable substrate, and the stamp pattern is transferred to the substrate after stamp is released from the substrate.

Soft PDMS(polydimethylsiloxane) has been widely used as a stamp material for soft lithography, which doesn’t requires heat or pressure. But it is not suitable for the imprint lithography due to weak mechanical strength like tensile strength or modulus. Some hard PDMS

was also tested as a stamp for the imprint lithography, although it is susceptible to fracture due to its insufficient toughness.

To overcome this problem, PDMS/epoxy composite material is used as a stamp.

2. Experiments

(1) Antistiction layer treatment on silicon master

Silicon master was dipped in piranha solution at 120℃ for 20 min, which is mixture solution of surfuric acid and hydrogen peroxide at 7/3 ratio. The silicon master was thoroughly washed with DI water, and transferred to vacuum oven. This silicon master is dried with vacuum and after 0.1mL perfluorodecyltrichlorosilane was added in the vacuum chamber at 110℃, and stand for 20 min.

(2) Stamp fabrication method

Sioxane oligomer and cross-linking agent was mixed at 10/1 ratio, and vapor in the mixture solution was removed under vacuum condition. The mixture solution was cast on adhesion promoter primed PET film manually, and its thickness was ca. 50μm. This film was stand for 5 min at 100℃ to control viscosity of the cast layer. The antiadhesion layer treated silicon master was pressed under vacuum for 2~4 hours at 150℃. After releasing the silicon master, its pattern was transferred to PDMS layer on the PET film.

(3) Imprinting procedure

PDMS stamp was pressed on partially cured epoxy layer supported by copper film under vacuum at 100℃ for 20 min. After this step, the temperature was raised to 130℃, and maintained for 1 hour. After PDMS stamp was released from epoxy layer, its pattern was transferred to epoxy layer

3. Results and discussion

PDMS/epoxy hybrid material was used to increase mechanical strength. The stamp of high epoxy contents is brittle, so its contents should be controlled for stiff stamp fabrication. Its optimum epoxy content was proved to be 20~30%, and the tensile strength was ca. 5 Mpa, and modulus was ca. 0.2Gpa at this condition.

Silicon master should be antiadhesion treated before it is used to fabricate PDMS stamp. Even though PDMS has low surface energy, it is difficult to release the silicon master from PDMS layer without any defect for high aspect ratio pattern. The surface of silicon master was treated with vapor SAM method using perfluorotrichlorosilane agent. The antiadhesion layer made with this method is convalently bonded with silicon substrate, and therefore its thermomechanical strength is excellent

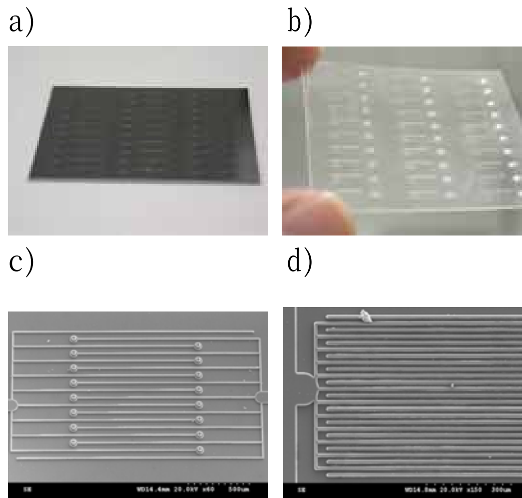


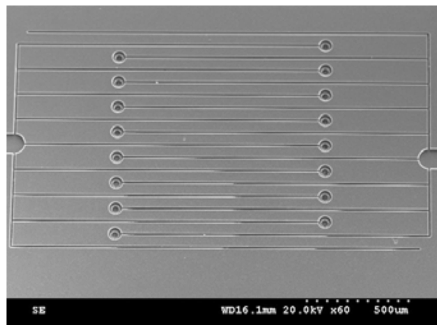
Fig. 5. The images of silicon master and PDMS

stamp a) optical image of silicon master b) optical image of PDMS stamp c,d) SEM images of PDMS stamp

Dielectric layer on copper plate was pressed under vacuum condition with antistiction treated silicon stamp. For silicon stamp with low epoxy contents its mechanical strength is not so sufficient that its pattern collapses during imprinting process. For high epoxy contents, silicone stamp is so hard that it is easily broken during demolding after imprinting process. The optimum epoxy content for silicone stamp in this imprinting process was proved to be ca. 30%. Silicon stamp of this epoxy content range has sufficient mechanical strength, and did not broken during demoding process (Fig. 6).

a)

b)



c)

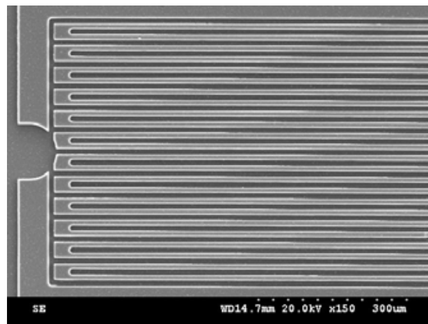


Fig. 6. Images of dielectric layer imprinted using silicone stamp. a) optical microscope image b,c) SEM images

4. Conclusion

Silicone stamp as a substitute for PUA stamp was fabricated, and its pattern was successfully transferred to the dielectric layer without any fracture during demolding process. The optimum epoxy contents for this silicone stamp were ca. 30%.

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