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후막 감광제를 이용한 100㎛ 두께 몰드 제작과 전해도금

정형균, 안시홍, 김용권
서울대학교 전기.컴퓨터공학부

Fabrication of 100㎛ thick mold and electroplating using thick photoresist

Hyoung-Kyoon Jung, Si-Hong Ahn and Yong-Kweon Kim
School of Electrical Engineering and Computer Science, Seoul National University

Abstract - Process conditions of a novel negative thick photoresist, JSR THB-430N®, are established in this paper. Although SU-8 obtains uniform and high-aspect-ratio structures, it is hard to remove the SU-8 mold after electroplating. The JSR THB-430N® can be more easily removed than the SU-8 and has a low internal stress. Introducing two step strip processes using acetone and the JSR THB-S1®, the JSR THB-430N® electroplating mold was removed completely and a JSR THB-430N® film stress is compressive less than 2 MPa. In this paper, we obatined 200㎛ thick PR structure and 100㎛ thick electroplated nickel structure using the JSR THB-430N® photoresist.

1. Introduction

Generally, SU-8 has been applied to not only the fabrication of tall micro structures, but also high aspect ratio molds for electroplating. According to the report of the SU-8, the SU-8 structures can be formed as high as 2.1mm [1] with 26 aspect ratio [2]. But the SU-8 has a high internal stress, so the SU-8 structures showed crack problems [2]. When the SU-8 structures are used as an electroplating mold, it is hard to strip the SU-8 electroplating mold. These SU-8's demerits restrict usages of SU-8 photoresist in spite of the merits of SU-8.

In this paper, we establish a process conditions of JSR THB-430N® negative photoresist which can replace SU-8 photoresist for thick plating mold application. JSR THB-430N® is a negative photoresist that can be 1.4 mm thick film using double coating process[1]. And THB-430N® can be easily removed by using acetone and THB-S1 stripper, and has a lower internal stress compared to SU-8. Because JSR THB-430N® has these above merits, we employ the JSR THB-430N® negative photoresist in order to electroplate 100㎛ thickness nickel structure.

2. Experiments

Figure 1 is a process flow of THB-430N® lithography. Ti/Au seed layer is deposited on the wafer. THB-430N® is coated on the seed layer and THB-430N® is baked to remove the solvent in photoresist. After exposure, THB-430N® is developed by using THB-D1 developer. Nickel is electroplated and THB-430N® electroplating mold is stripped by using acetone and THB-S1 stripper.

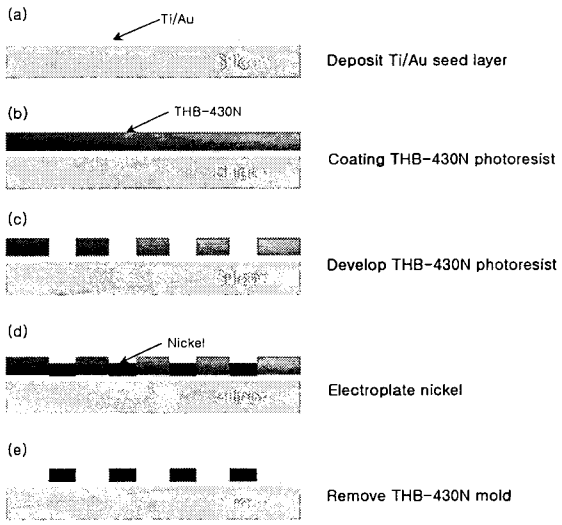


Fig. 1 Fabrication process of THB-430N® mold

THB-430N® spin coating

A photoresist thickness versus spin speed is shown in Fig 2. In this paper, the THB-430N® film is coated from a thickness of 57㎛ to 200㎛ for test. At first THB-430N® is dispensed on the wafer,

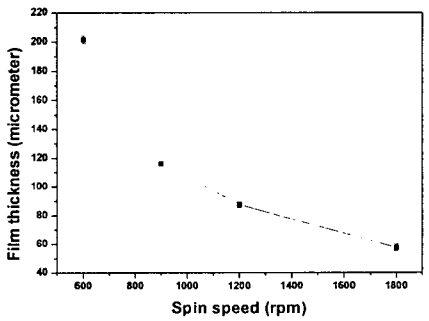


Fig. 2 Spin speed versus film thickness

and the PR is spread at 300 rpm for 10 seconds. Pre-spin speed and time are fixed at these value, and we control main-spin speed. The variation of

main-spin speed is from 600 rpm to 1800 rpm. And the main-spin time is fixed at 10 seconds.

Soft bake

After PR coating on the wafer, a soft bake process is performed to remove solvent in the PR. In experiments, THB-430N® is baked at 100°C on hot plate for 10 minutes in the case of 115㎛ thickness THB-430N® film.

Exposure and development

The THB-430N® film is exposed by UV-light, whose wavelength is 405 nm at various exposure energy level. THB-430N® film is developed by using THB-D1(0.5% TMAHaq.) developer for 13 minutes with agitation. Because a main stress of a thick photoresist film is generated during the PEB(Post Exposure Bake) and hard-baking [4], THB-430N®, which does not require PEB process, can have a low film stress. Therefore, THB-430N® has a lower internal stress than SU-8.

Nickel electroplating

With the obtained results, a nickel electroplating was performed. The thickness of PR mold and the electroplated nickel are 115 ㎛ and 100㎛, respectively. A nickel sulfamate bath was used as a plating bath. An electroplating rate is 0.9 ㎛/min when a current density is 50 mA/cm^2. It is well known that some additives in the electroplating bath improve a quality of electroplated nickel. To prevent pitted deposits, anionic wetting agents are used, which do not affect the ductility or stress of the plate. Mechanical stirring of solution performed continuously during the electroplating.

Removing of THB-430N® photoresist mold

THB-430N® electroplating mold is easily stripped compared to the SU-8 mold. Removing the THB-430N® electroplating mold, we use two step removing processes. At first, THB-430N® mold is dipped in acetone to soften the adhesion between resist and seed layer. And then, a softened THB-430N® mold is dipped in THB-S1 stripper at 70°C to remove the photoresist residue completely.

3. Results and Discussion

100 ㎛ thick THB-430N® photoresist

In order to measure a film stress of THB-430N® photoresist, whose thickness is 115 ㎛, we used the Tencor FLX 2320 Strain Gauge. The measured stress is compressive and less than 2 MPa. Because PEB process is not required in the THB-430N® lithography, it has a low film stress.

Fig. 3 shows the THB-430N® structures made with various exposure energy. The expose energy is varied from 2400 mJ/cm^2 to 8400 mJ/cm^2. When THB-430N® is exposed by UV-exposure energy over 8400 mJ/cm^2, the electroplating mold cracks after electroplating. Because the THB-430N® is a negative photoresist, the negative slope of PR sidewall is appeared.

Fig. 4 shows the relationship between the exposure energy and the vertical angle of PR sidewall. All side wall angle of the PR structures are 84° and more from 2400 mJ/cm^2 to 8400 mJ/cm^2 of the exposure energy, especially a vertical side wall angle of 87.3 ° is shown at 6000 mJ/cm^2.

In Fig. 5, the width of PR pattern according to the exposure energy is shown. A negative photoresist is used in this research. So, when the small quantity of exposure energy is used, the width of the PR pattern become larger. And when the large quantity energy is exposed, the pattern width become larger. The pattern width of a used photo mask is 100 ㎛. Therefore, we determine the dose of the exposure energy with the results of the side wall angle of the PR structure and the width of the PR pattern structure.

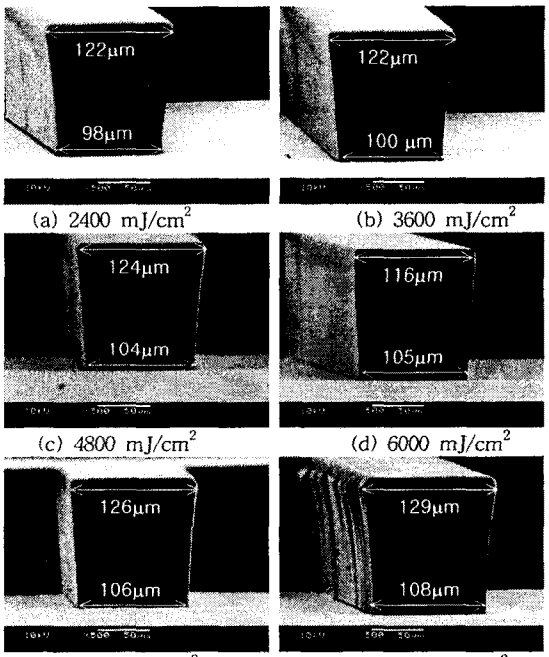


Fig. 3 100 ㎛ thick THB-430N® photoresist

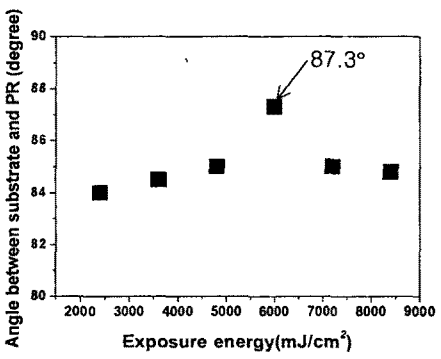


Fig. 4 Exposure energy versus angle between substrate and PR

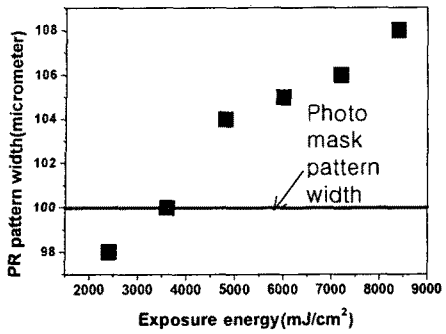
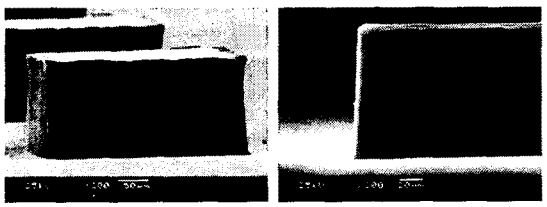


Fig. 5 Exposure energy versus PR pattern width

100 μm thick electroplated nickel structure

Electroplated nickel structure of 100μm thick is shown in Fig. 6. The pattern size is 200 μm × 200 μm. The rabbit-ear effect is observed in Fig. 6(a), owing to the concentration of current density. This effect can be reduced and enhance the uniformity in the pattern by some additives. As mentioned above, THB-430N® electroplating mold is completely removed by being adopted two step stripping process. Note that there is no photoresist residue in Fig. 6



(a) (b)

Fig. 6 Electroplated 100 μm thickness nickel structure

4. Conclusion

This paper reported the process conditions of a novel negative thick photoresist, THB-430N®. Compared with the SU-8, the THB-430N® has a low internal stress and is easy to strip, when it is used electroplating mold. We adopt two step removing process using acetone and THB-S1. JSR THB-430N® electroplating mold can be removed completely and THB-430N® film stress is measured compressive and less than 2 MPa. In this paper, we obtained 115 μm thick PR structure and 100 μm thick electroplated nickel structure using THB-430N® photoresist mold.

Acknowledgements

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