第 25 卷第 1 期 半 导 体 学 报 Vol. 25, No. 1
2004 年 1 月 CHINESE JOURNAL OF SEMICONDUCTORS Jan., 2004

A New Method for Fabrication of SU8 Structures with a High Aspect Ratio Using a Mask-Back Exposure Technique*

Yi Futing[1], Miao Peng[2], Peng Liangqiang[1], Zhang Jufang[1] and Han Yong[1]

(1 *Institute of High Energy Physics, The Chinese Academy of Sciences, Beijing* 100039, *China*)
(2 *Imperial Collage London, London SW7 2BT, UK*)

Abstract: A new method is presented, which can obtain high aspect ratio in SU8 structures. Instead that the top of the photo resist layers are exposed to UV light through masks in conventional lithography, the new method utilizes a mask-back exposure technique, i.e. the SU8 resist layer coated on a mask surface (metal patterns on a glass plate), is irradiated by UV light through the back of the mask. So a desired exposure dose on the bottom of the resist layer can be easily achieved without over-exposing from its top. This has a two-fold effect, i.e. proper dose on the bottom of the resist and less internal stress. Initial experimental results show that compared to an aspect ratio of 18 obtained by conventional method, a higher aspect ratio of 32 in the SU8 structures can be achieved by this new method.

Key words: MEMS; SU8 resist; microfabrication; back-exposure.
EEACC: 0170G; 2220C
CLC number: TN405 **Document code**: A **Article ID**: 0253-4177(2004)01-0026-04

1 Introduction

SU8 is an epoxy based, chemically amplified resist with a high sensitivity, which is widely used in the MEMS for the fabrication of primary structures[1,2]. The unique advantage of a SU8 resist is that the structure height fabricated with the SU8 resist can reach near 1mm. Its high aspect ratio (above 15) makes the SU8 an ideal material used as a resist mask for RIE and a primary mould for electroplating in the fabrication of many devices[1~5]. Being a negative resist, the SU8 resist will be polymerized into cross-linked structures during the exposure to the UV light. This polymerization will cause internal stress in the resist layer, which, in turn, leads to poor adhesion of the resist to the substrate if it is over-exposed. Sometimes, the excess internal stress may lift the resist layer off the substrate. To reduce the internal stress in the SU8 resist, the exposure dose has to be controlled to a minimum level. This often causes the bottom of the resist under-exposed. Therefore, the SU8 resist near the substrate is often dissolved in a developer due to less cross-link reaction hence a poor definition[1].

The new method to be described in this paper can reduce the internal stress without sacrificing the desired exposure dose in the bottom of the resist layer. The basic idea of this approach is a specially designed UV mask. This mask is fabricated using normal UV lithography and wet etching processes. Basically, this mask, which also serves as a substrate, is a glass plate with some metal (in this case, chromium) patterns on it. These patterns are not only used to block the UV light like conventional masks, but also used as a seed metal layer for electroplating in subsequent process. It should

* Project supported by National High Technology Research and Development Program of China(No. 2002AA404150)
Received 12 May 2003, revised manuscript received 28 July 2003

be pointed out that this metal layer has to be compatible with the metal to be plated.

2 Details of fabrication

Conventional masks with the chromium and oxide chromium patterns are used for lithography only. While the special mask addressed here has both functions of traditional masks and substrates. The details of the fabrication process are shown in Fig. 1.

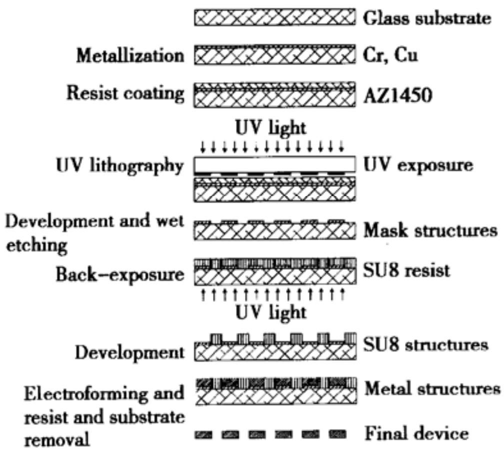

Fig. 1 Fabrication process for exposure of SU8 resist through the back of a mask

Firstly, the glass substrate is metallized with chromium or copper and then patterned by standard UV lithography and wet etching techniques. Secondly, a SU8 resist layer with a desired thickness is directly coated on the metal patterns of the mask, and then followed by pre-bake process. For a 300μm SU8 resist layer, the pre-bake temperature in oven is set at 95℃ for 30min. After that, SU8 resist layer is exposed to UV light through the back of the mask at a dose of 1.2kJ/cm^2 with the light intensity of 1W/cm^2 and the exposure time of 20min. After UV exposure, the resist layer is post-baked in oven at 85℃ for 20min, and then is developed in SU8 developer commercially produced by MicroChem Corp. for 30min. This prolonged development will ensure all un-exposed areas in resist layer to be dissolved in the developer completely[1]. This long time to develop the SU8 structures can provide the structure with the same exposure dose profile. Finally, the metal patterns are electroplated to a desired height using the SU8 resist as a mould and de-moulded from the substrate.

3 Results and discussion

The SU8 resist is very sensitive to the UV light. The exposure time has significant influence on the definition of the SU8 structures. Conventional lithography technique often makes SU8 structures have smaller lateral size in the region near the substrate due to under-exposure in that region[1]. This greatly reduces the strength of the structures. Sometimes they are "washed away" in developer. In order to ensure a desired exposure dose in the region near the substrate, the resist layer has to be over-exposed. However, over-exposure will induce larger internal stress which will lead poor adhesion between the resist layer and the substrate, hence poor strength of the structures again. It is found difficult to overcome this problem in fabrication.

The new method presented in this paper, utilizing "back-exposure" technique, has been proven to be a proper solution to this problem. Exposure through the back of the mask will ensure the bottom of the resist layer to be exposed at a desired dose without over-exposing the entire resist layer. Therefore, the SU8 structures fabricated in this way will be strong and have a good adhesion to the substrate. Figure 2(a) shows a structure of four letters fabricated with SU8 by back-exposure for 20min. This structure has a lateral size of 10μm and a height of 320μm, which gives a high aspect ratio of 32. This is much higher than aspect ratio of 18 achieved using conventional exposure technique. From Fig. 2(a), it can be seen that the top of the structure is slightly dissolved by developer due to under-exposure, but this structure can stand on the substrate firmly. A similar SU8 structure fabricated using the same technique, shown in Fig. 2

(b), has a lateral size of 20μm and a height of 400μm. The only difference between the two is that exposure time employed in Fig. 2(b) is 35min. In Fig. 2(b), a 10μm expansion in lateral size can be observed due to prolonged exposure.

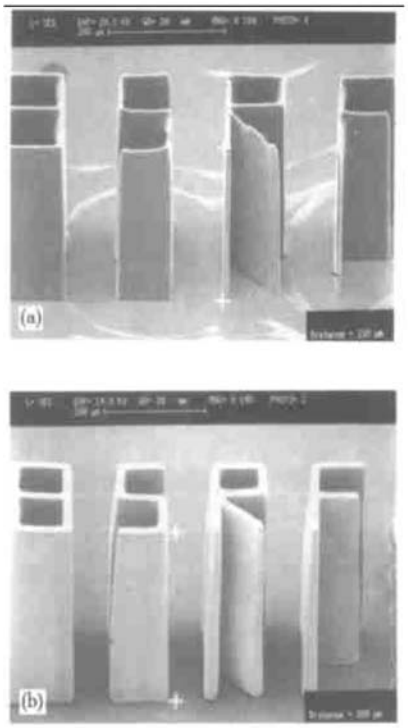

Fig. 2 SU8 structures fabricated by back-exposure technique (a) Exposed for 20min; (b) Exposed for 35min

Although the back-exposure technique can be used to solve the difficulties of poor adhesion and poor strength of the SU8 structures as discussed above, its application in fabrication of ultra high structures (e.g. a few millimeters) is still limited. This is because the top of the structures may be dissolved in developer due to under-exposure, as seen in Fig. 2(a). The higher the structures are, the more SU8 will be dissolved on the top. However, this limitation can be overcome by multiple back exposure technique. In this case, A second SU8 resist layer is coated on the top of the mixed structure of SU8 and metal after the gaps formed by SU8 structures are fully filled by electroformed metal (step of "Electroforming" in Fig. 1). And the SU8 layer is exposed to UV light through the back of the mask again. This time, the exposure dose has to be higher than that employed in the first step in order to penetrate the SU8 formed in the first step. Although the higher exposure dose will induce larger internal stress in bottom of the resist layer, this stress will not lift the resist layer off the substrate because the electroformed metal structures fix the SU8 structures. The second SU8 structures will be used as a mould for further electroforming. The one of the advantages of this multiple back exposure technique is that no alignment is needed for the second exposure. This back exposure process can be used several times until a desired thickness is achieved. Figure 3 shows the structure of a heat exchanger, which is fabricated using the back exposure process twice. This copper comb structure has a height of 0.6mm which is electroformed by two 300μm thick SU8 moulds.

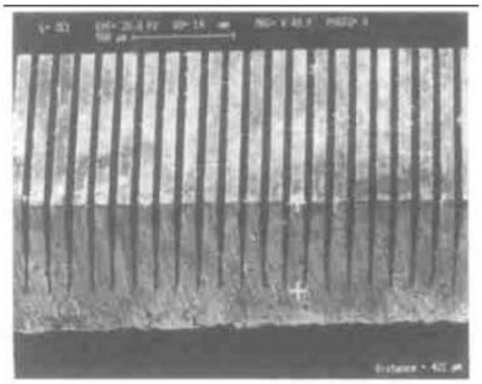

Fig. 3 A copper comb structure fabricated using back exposure process twice

4 Conclusion

A new method is developed for fabricating thick SU8 structures. Experimental results show that an aspect ratio of 32 can be achieved by this new method. This is much higher than aspect ratio of 18 obtained by conventional exposure process. Ultra high structures can be fabricated by multiple back exposure technique. A unique advantage of this multiple back exposure technique is that no alignment is needed. This will greatly simplify the fabrication process hence reduces the cost.

References

[1] Despont M, Lorenz H, Fahrni N, et al. High-aspect-ratio, ultrathick, negative-tone near-UV photoresist for MEMS applications. Proc of the 10th Int IEEE Workshop on Microelectro Mechanical Systems, 1997: 518

[2] http: // dmtwww. epfl. ch/ims/micsys/projects/su8

[3] Lee K Y, LaBianca N, Rishton S A, et al. Micromaching application of a high resolution ultrathick photoresist. J Vac Sci Technol B, 1995, 13(6): 3012

[4] Lorenz H, Despont M, Vettiger P, et al. Fabrication of photoplastic high-aspect ratio microparts and micromolds using SU-8 UV resist. Microsystem Technologies, 1998, 4: 143

[5] Cremers C, Bouamrane F, Singleton L, et al. SU-8 as resist material for deep X-ray lithography. Microsystem Technologies, 2001, 7: 11

利用背面曝光技术制造大高宽比 SU8 结构的一种新方法*

伊福廷[1]　缪　鹏[2]　彭良强[1]　张菊芳[1]　韩　勇[1]

(1 中国科学院高能物理研究所, 北京　100039)

(2 英国帝国理工医学院, 伦敦)

摘要: 提出了一种解决大高宽比 SU8 结构的新方法. 该方法是将 SU8 胶涂在一块掩模上, 紫外光从掩模的背面照射, 这样 SU8 胶的曝光将从底部开始, 不需要进行过曝光来保证底部胶的曝光剂量, 从而很容易控制曝光剂量和 SU8 胶结构的内应力. 实验结果表明, 该方法能够得到高宽比为 32 的 SU8 结构, 而文献报道的 SU8 胶结构的高宽比最大仅为 18.

关键词: MEMS; SU8 胶; 微加工; 背面曝光

EEACC: 0170G; 2220C

中图分类号: TN405　　**文献标识码**: A　　**文章编号**: 0253-4177(2004)01-0026-04

* 国家高技术研究发展计划(No. 2002AA404150)资助项目

2003-05-12 收到, 2003-07-28 定稿