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Incident Angle Effect on Deep MEMS Structure in Resist Spray Coating Technique

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1. Introduction

Deep microstructures having high aspect ratio are frequently required in MEMS. The resist spray coating has gathered a significant attention because it has a large potential for realizing the true three-dimensional structures using photolithography. Uniform resist coverage over deep cavities with little restriction is a strong advantage [1,2]. Up to now, we have demonstrated the lithography on anisotropically wet-etched Si cavities [3] and optical fiber ends [4] using the originally developed spray coating system. Optical scanner with the three-dimensional structure is also demonstrated [5]. Although some technical demonstration has successfully shown, the fundamental understanding or the organized information about process conditions has not been clarified. As a matter of fact, pinholes are inevitably generated with the increase of the aspect ratio. Figure 1 shows the relation between them. According to this data, designing the low aspect ratio structure is the simplest method to over come this problem. A technique has been demonstrated to remove the pinholes by enhancing the migration of resist after the spray coating [6]. This is at a cost of thinning the convex corner coverage. Figure 2 is an image of the patterned photo-resist across the 50μm-deep step after using this technique. The resist pattern is obtained without the disconnection at the convex corner of the cavity, where is difficult to maintain the resist coverage. In this condition, the photo-resist thickness >1 μm is obtained. The method that can directly deposit the resist film with low pinhole density over high aspect ratio structures is much attractive. In this study, the effect of the inclination of the sample is examined.

2. Experiments

Figure 3(a) is the experimental set up of originally developed resist spray coating equipment. The detail is in reference [2]. The sample is KOH etched Si (100) wafer having rectangular cavities with the depth of 200 μm. By designing different sizes of rectangle, microstructures having different aspect ratio are prepared. Here, the aspect ratio is defined by cavity depth/{(width + length)/ 2}. The sidewall surface is 55 degrees slant against the substrate. The used resist is OMR83 60cp negative resist (Tokyo Ohka Kogyo Co., Ltd.) diluted to 5% in volume using *p*-xylene solvent.

Figure 3(b) shows the sample setup during spray coating. The resist spray flows from the upside. Pinholes are counted using the optical microscope at the relief mode under the edge illumination for increasing the contrast. The typical sizes of pinholes are 6-10 μm.

3. Results

Figure 4 shows the typical surface morphology of the cavity covered with the sprayed resist. The relative position of the sidewalls (1and 2) against the spray nozzle is shown in Fig. 3 (b). The downstream surface is called by sidewall (1). Fundamentally, pinholes are observed near to the bottom. Comparing all surfaces in the Si cavity, the bottom surface has the high pinhole density. This will be related to the supplying mechanism of the resist inside the cavity. Figures 4(a) and 4(b) are observed, when the sample is placed horizontally and at 30 degrees, respectively. As seen from Fig. 4(b), pinhole density increases except for the sidewall (1) between Figs.4 (a) and 4 (b). The incident angle to the sidewall (1) decreases from 55 to 25 degrees. On the other hand, the incident angle increases from 55 to 85 degrees for opposite sidewall (2) and the pinhole density increases very much. The typical size of pinholes becomes 2-4μm.

Figure 5 shows the pinhole density at 200μm-deep cavity bottom, placing the sample at different angles. With the increase of the incident angle, the pinhole density increases a lot. A certain run-by-run fluctuation of pinhole density is observed as seen from data at 0 degree incident angle. Notice that pinhole density value increases about 10 times by inclining the surface.

Figure 6 shows the pinhole density on different surfaces of the cavity having the same aspect ratio of 0.32. For all surfaces of the cavity, pinhole density increases with the increase of incident angle. Not only the cavity bottom but also the top Si surface has the pinhole, although the aspect ratio is zero. Therefore, the incident angle is an important parameter for the pinhole density. By controlling the incident angle at 0 degree, the pinhole density can be reduced, however does not decrease to null. Small number of pinholes remains near to the bottom edge.

4. Conclusions

The pinhole density strongly depends on the incident angle of the resist flow on the microstructure, although the aspect ratio is also an important factor. By decreasing the incident angle of the resist flow to all surfaces of the cavity, the pinhole density can be reduced.

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References

[1] V.K. Singh, M. Sasaki, J.H. Song and K. Hane: Jpn J. Appl. Phys. to be published in June (2003).

[2] N.P. Pham, T.L.M. Scholtes, R. Klerk, B.Wieder, P.M. Sarro and J.N. Burghartz: Proc. SPIE 4577(2001) p. 312.

[3]. M. Sasaki, S. Nogawa and K. Hane: Trans. IEE Jpn. 122-E (2002) p.235 (*in Japanese*).

[4]. M. Sasaki, T. Ando, S. Nogawa and K. Hane: Jpn. J. Appl. Phys. 41 (2002) p.4350.

[5]. M. Sasaki, T. Yamaguchi, J.H. Song, K. Hane, M. Hara and K. Hori: J. Lightwave Technol., Mar. (2003) (in press).

[6] V.K. Singh, M. Sasaki, J.H. Song and K. Hane: Proc. Transducers'03.

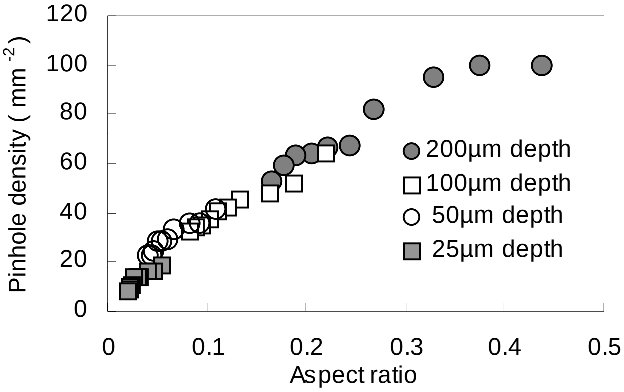

Figure 1. Pinhole density at the cavity bottom as a function of aspect ratio.

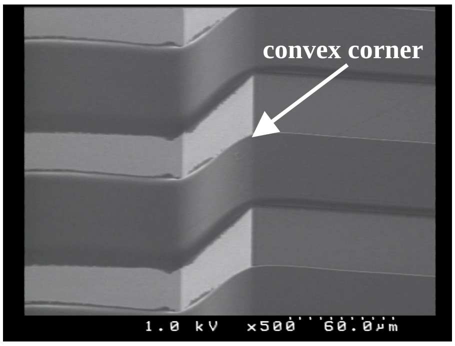

Figure 2. SEM image of patterned photo-resist over 50µm deep step.

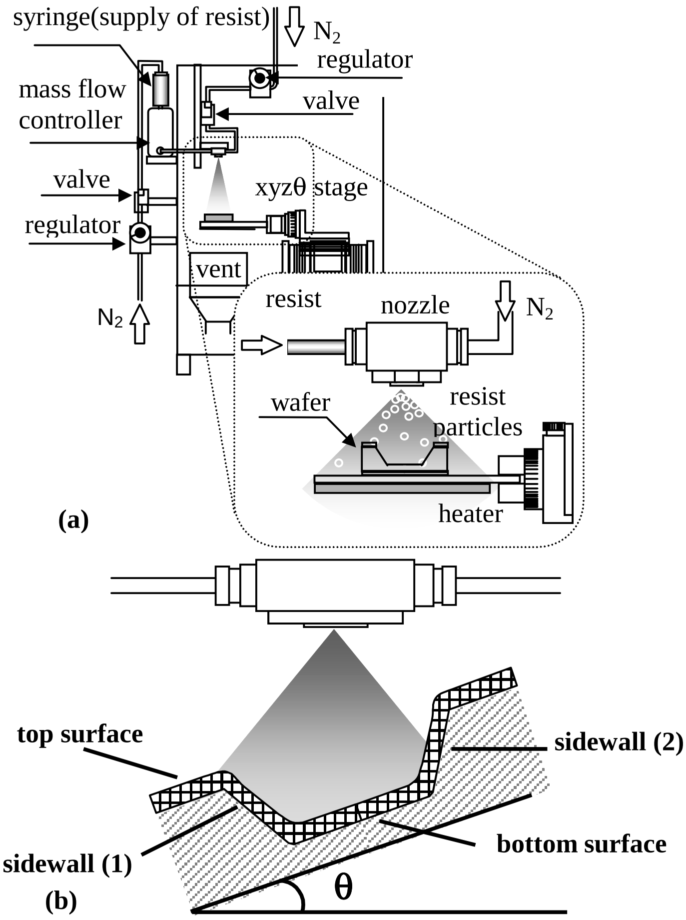

Figure 3. **(a)** Experimental setup of resist spray coating equipment. **(b)** Sample setup during spray coating.

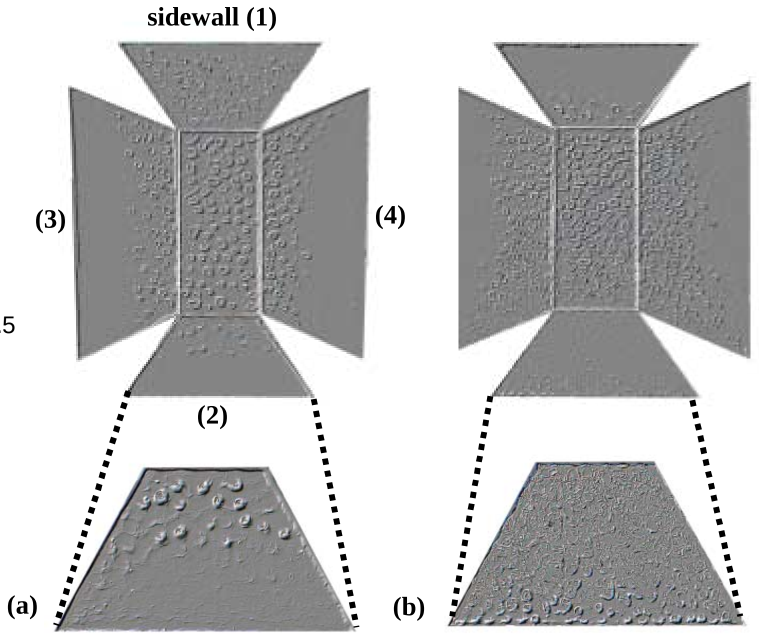

Figure 4. Typical surface morphology of the resist spray coated cavity with relative sidewalls at (a) 0 & (b) 30 degree angle.

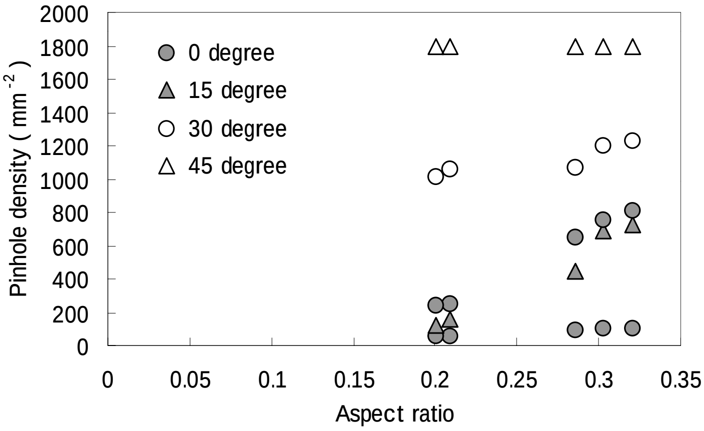

Figure 5. Pinhole density at 200µm bottom surfaces as a function of aspect ratio of the cavities on different angles.

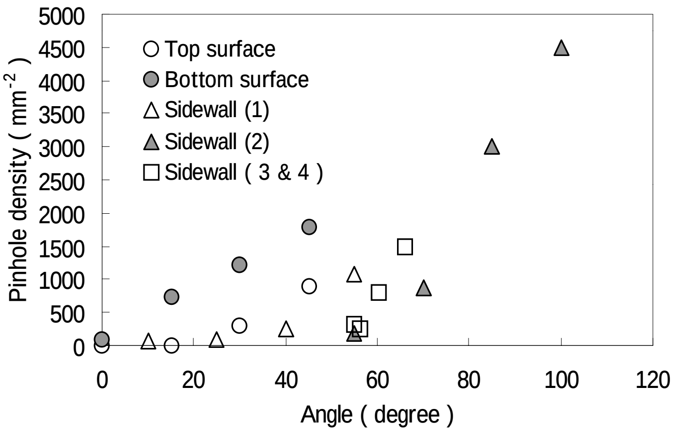

Figure 6. Pinhole density on all surfaces of the 200µm deep cavity as a function of incident angle.