HIGH FILL-FACTOR MICROMIRROR ARRAY AND ITS FABRICATION PROCESS

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Abstract – The micromirror array with high fill-factor of 91% is fabricated. For high fill-factor, the posts supporting the mirror plate are filled up with copper by the uniform electroplating process.

1. Introduction

Fill-factor directly related to the contrast ratio is very important factor in a micromirror array for display applications. In case of the DMD (Digital Micromirror Device) of Texas Instruments which has been used as the core device in the DLP (Digital Light processing), optical reflection efficiency is degraded because of light diffraction mainly caused by the hole in the center of the mirror plates [1]. We introduced a new digital miromirror device using interdigitated cantilevers as shown in Fig. 1 [2]. However, we cannot fabricate the micromirror array with the uniform mirror surface because electroplating process for the posts and mirror plate at once is not uniform. In this work, the post holes supporting mirror plates are filled up using the surface micromachining process of uniform metal electroplating, and a high fill-factor and a uniform mirror surface in 2-dimensional micromirror array are achieved.

2. Experiment and fabrication

In order to fabricate the micromirror array composed of multi-level metal microstructures, we used a metal surface micromachining based on the plating-through-mask method [3]. The micromirror structure is made of electroplated copper and a thick photoresist mold is employed as a sacrificial layer.

Figure 2 shows the cross sectional views of the fabrication steps. Especially, to fill up support posts, lower posts are electroplated up exactly to the height of the patterned photoresist mold as shown in Fig 2(b). Also, upper posts supporting mirror plates are electroplated up in the same way of Fig 2(f). By these processes, the support posts can be simply filled up without limits of heights and widths. Figure 3 shows SEM images of the post array fabricated by the copper pulse reverse electroplating. The left is the array of posts with various sizes of 20μm×10μm or 10μm×10μm. The other is all 2μm square posts. The uniform height of posts can be acquired even in the case of various pattern sizes or a few micrometer sizes. The RMS surface roughness of the copper posts is about 84Å by AFM.

3. Results

Figure 4 shows the fabrication results of the micromirror array. The array of 100μm square micromirror is shown in Fig. 4(a). The error depth of hole in topmost mirror plate is below 0.7μm, which is measured by an optical surface profiler. This micromirror has rotated an angle of 6° at the bias voltage of 57V, which is a pull-in voltage as shown in the hysteresis curve of Fig. 4(a). The micromirror array of 50μm square cells is shown in Fig. 4(b). The distance between each cell is 5μm. In this case, the surface hole caused by the support posts is almost perfectly removed. Therefore, this makes it possible to achieve very high fill-factor of about 91% in a 2-dimensional array.

4. Conclusions

We have fabricated the high fill-factor micromirror array using a simple surface micromachining of uniform electroplating process. This micromirror array can be used for display applications with a high optical efficiency and a high contrast ratio.

[References]

[1] P. F. Van Kessel, et al, "A MEMS-Based Projection Display", *Proceedings of The IEEE*, vol. 86, pp. 1687~1704, Aug. 1998.
[2] Jin-Wan Jeon, et al, "Electrostatic Digital Micromirror Using Interdigitated Cantilevers", *IEEE Int. MEMS Conf. Tech. Dig.*, pp. 528~531, 2002.
[3] Romankiw, L. T., and O'Sullivan, E. J. M., "Chapter 5: Plating Techniques," *Handbook of Microlithography, Micrormachining, and Microfabrication, Vol. 2: Micromachining and Microfabrication*, editor: P. Rai-Choudhury, pp. 241. co-published by SPIE and IEE, 1997.

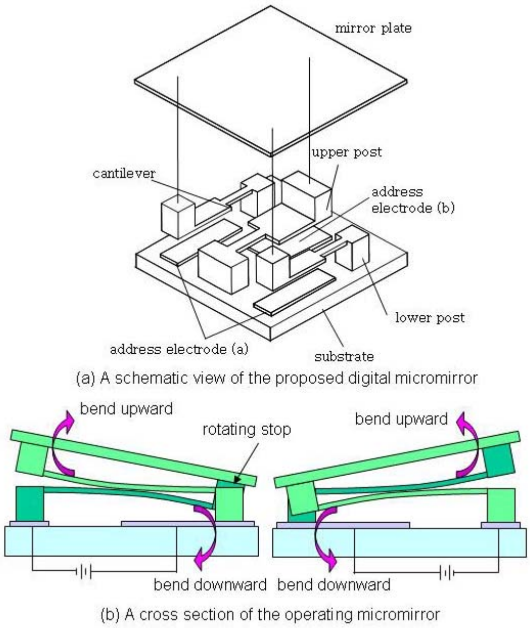

Figure 1. Schematic views of the micromirror device and its operation principle [2]

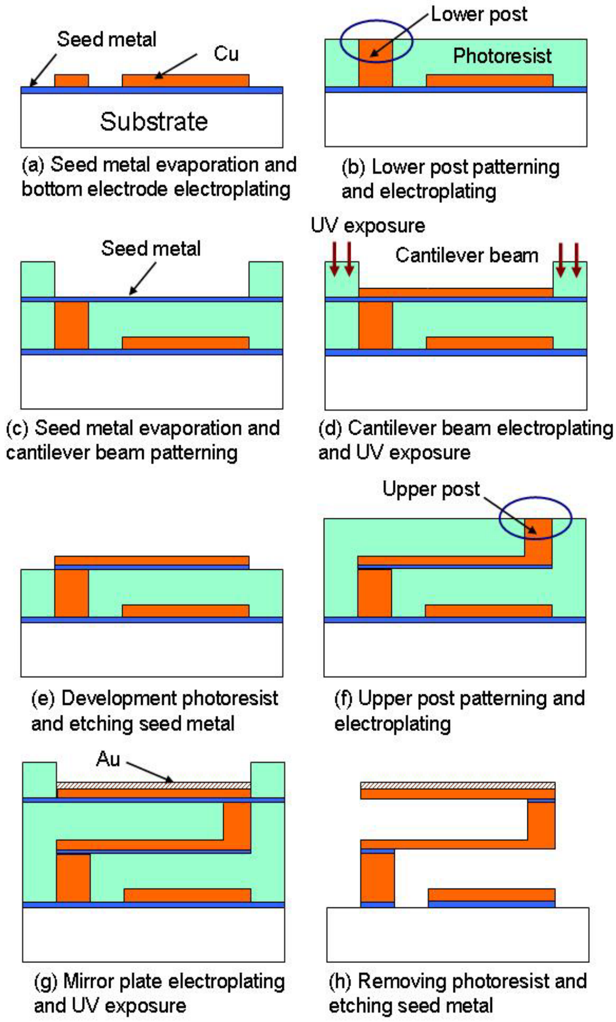

Figure 2. Fabrication steps

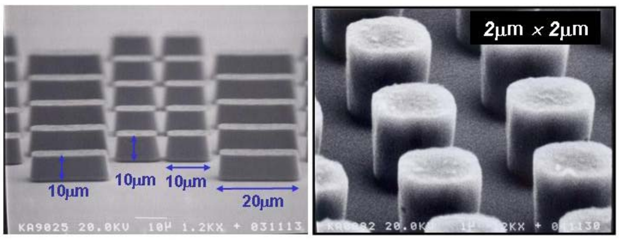

Figure 3. SEM images of various dimensions of eletroplated posts

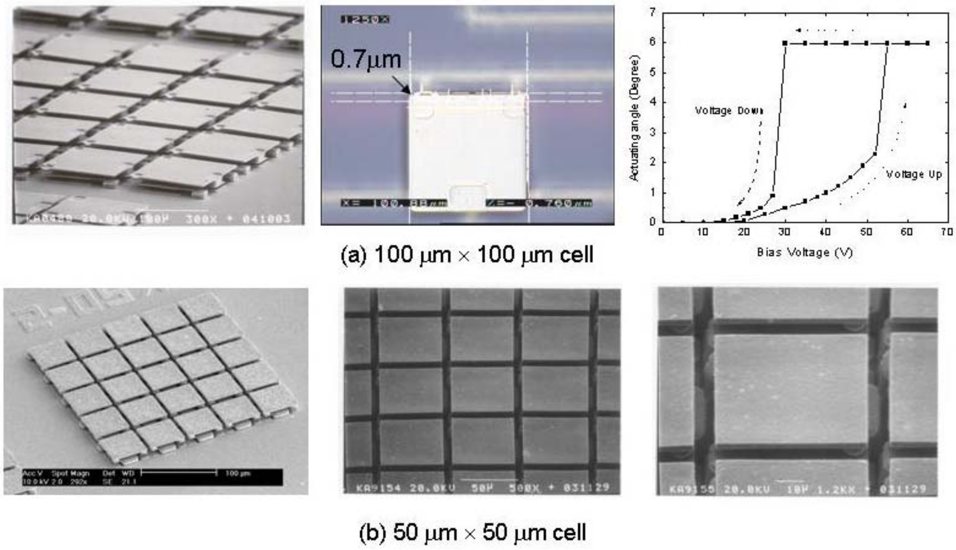

Figure 4. Fabrication results of high fill-factor micromirror arrays