

MEMS Based Light Modulator

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Abstract— This paper presents a simple way to build a MEMS based light modulator. Here Aluminum ribbons are suspended in an air gap. An array of these Al ribbons can be used to act as a light modulator. Alternate Al ribbons are connected to a DC bias of 50V which will curve downwards due to the stress applied and electrostatic attraction. Thus, the light intensity can be modulated to any shade of gray needed or even turn it off completely. Different sizes of light modulators were built using Mentor Graphics and were fabricated in the RIT, SMFL. Final results did not work as desired due to the bending of the aluminum ribbons for 800 μm long Al ribbons. 80 μm long Al ribbons, in contrast, were suspended.

Index Terms— MEMS, Mentor Graphics, Modulator

I. INTRODUCTION

MEMS (Micro Electro Mechanical Systems) is one of the most promising engineering field. At present, MEMS engineering is in use in optical switches, networking systems, accelerometers in automotive bags, inkjets in printer as well as sensors in medical testing equipment.

Light modulators are devices that changes the intensity of incident light to any shade of needed gray. This is also referred to as grayscale. Under proper biasing, destructive interference will make the signal turn completely dark. At present, they are optical modulators are used for color display matrix as well as optical networking systems.

This paper present a simple way to build a light modulator using aluminum metal to build the air bridge as it is highly reflective and readily available. When alternate air bridges are connected to a DC bias of 50 volts, they will bend downwards due to the stress applied. The downwards movement will be determined by the wavelength of the incident light. It was calculated to be around 1.1 μm as it is also the thinnest resist thickness the tool could coat. This turned out to be $7/4 \lambda$ of the incident light. Therefore, in an actuated state, the diffracted light will have to travel an extra distance leading it to be 180° out of phase or also causing destructive interference. The theory behind this application is shown by Fig. 1.

This work is part of capstone design project for a B.S. degree in Microelectronic Engineering at the Rochester Institute of Technology (RIT), Rochester, NY. The results of the project were first presented as part of the 23rd Annual Microelectronic Engineering Conference, May 2005 at RIT.

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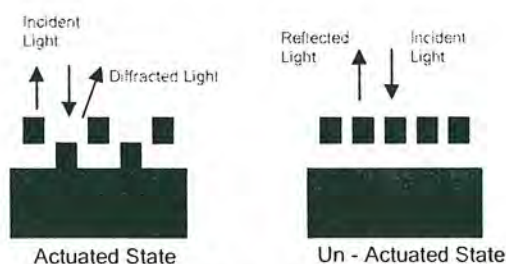


Fig. 1: Theory behind Light Modulator Design.

II. DESIGN

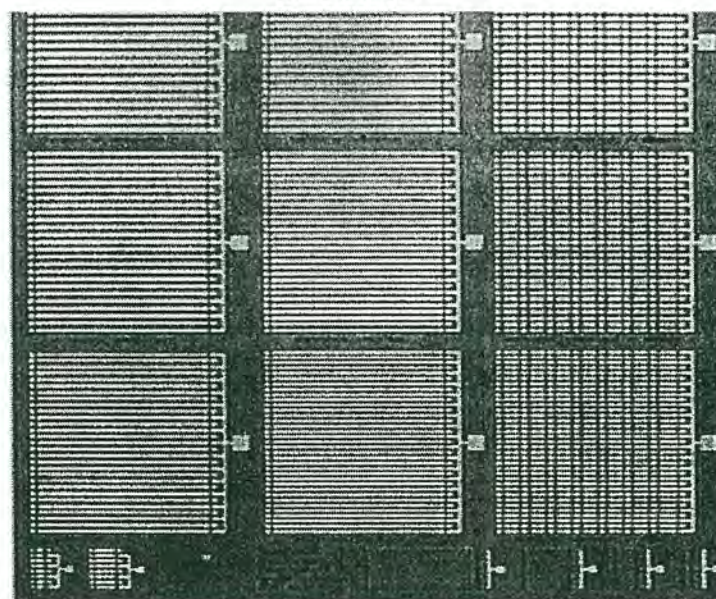
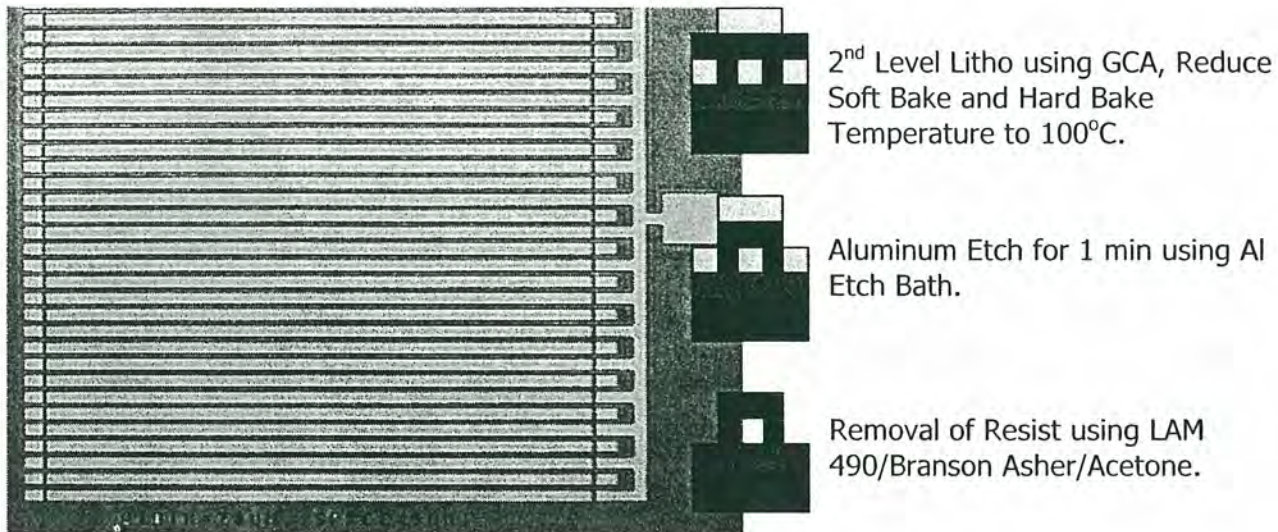


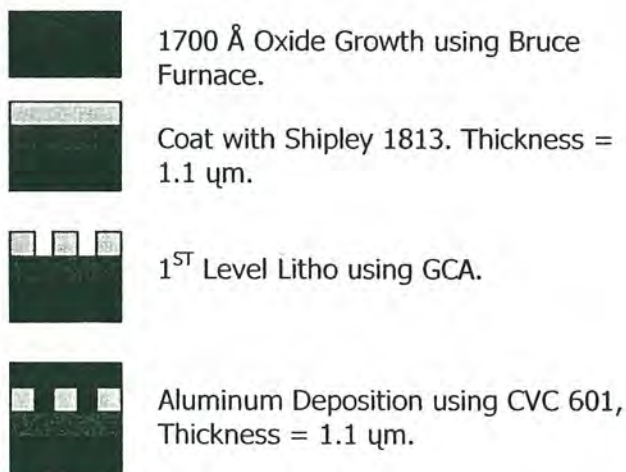
Fig. 2: Mask layout of devices using Mentor Graphics.

Fig. 2 illustrate the final mask design layout for fabricating the modulators. An array of different Al widths and gap spacings ranging from 800 to 20 μm was designed. The reasoning underlying the device size variation was to provide a series of test structures in the even that the longer structures were not suspended. As will be detailed in later sections of this paper, these shorter suspensions spans were found to work, whereas longer spans effectively collapsed.

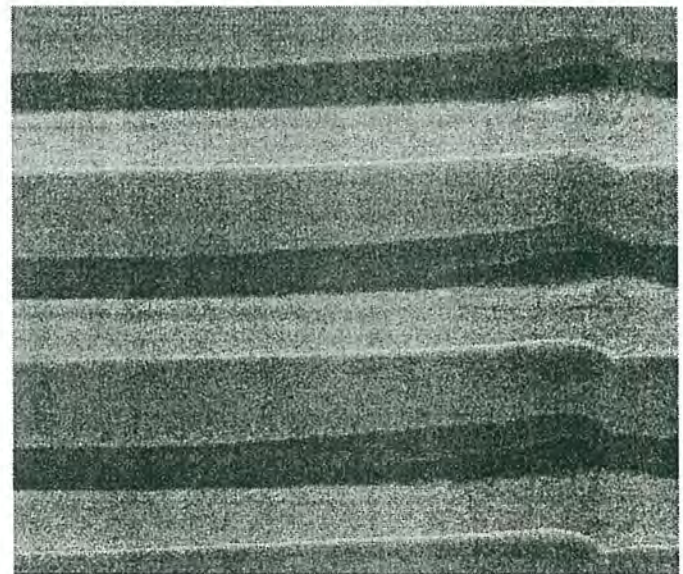
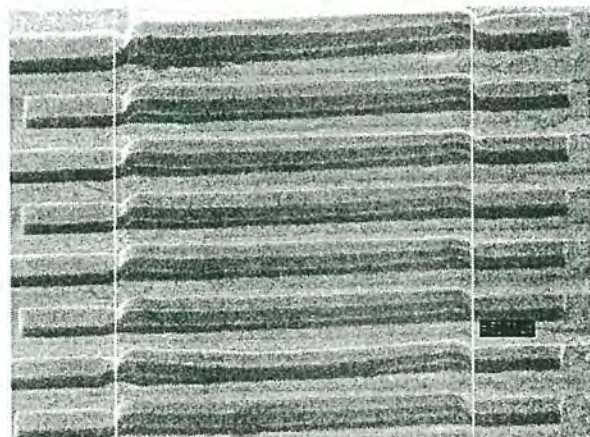
Fig. 3: Image of a 800 μm Device layout.

III. EXPERIMENTAL

All the fabrication was done at the RIT, SMFL fab. Detailed below are the fabrication steps. The process consisted of two lithography steps performed using the GCA g-line stepper. The first level patterned, termed the post, consists of an opening that will provide mechanical support for the airbridge. The resist profile is intentionally designed to have a tapered profile, as this will provide mechanical support for the metal to form in the shape of an arch. A desired thickness of Al is then sputtered on the sample. This thickness is typically found to be between 500nm to 1 μm . A second lithography step is then performed to pattern the Al, which is subsequently defined by a wet etch. The underlying resist from the first exposure is then removed by a combination of acetone stripping and O₂ plasma via the Branson Asher. The end result are a series of suspended Al lines.



IV. RESULT

Fig. 4: SEM picture of 800 μm device.Fig. 5: SEM picture of 50 μm device.

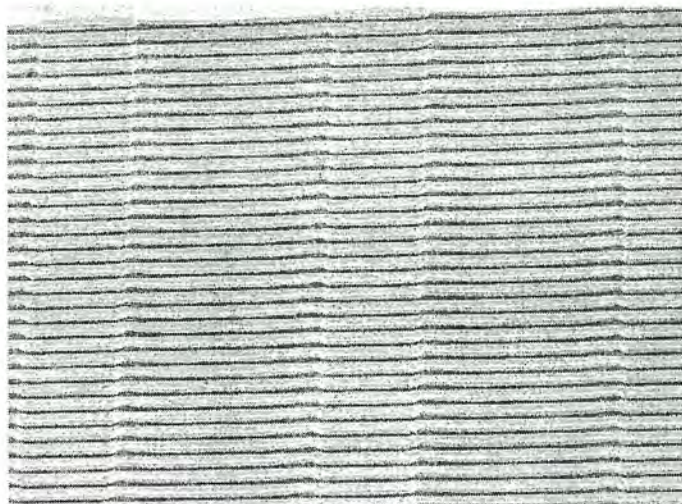


Fig. 6: SEM picture of 800 μm device with anchors every 80 μm .

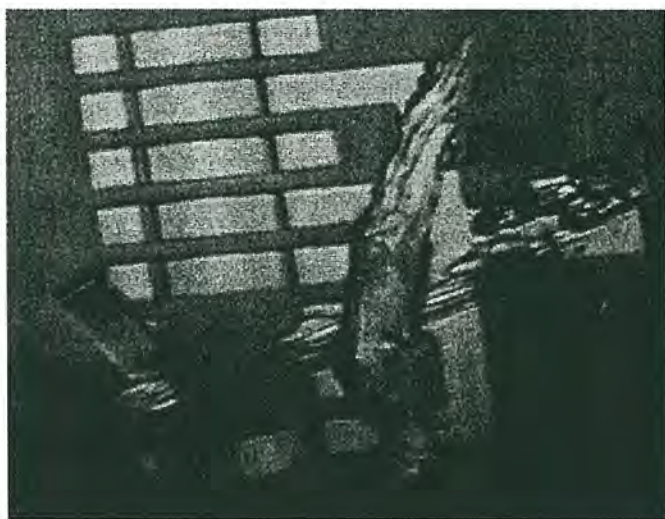


Fig. 7: Image showing no underlying resist.

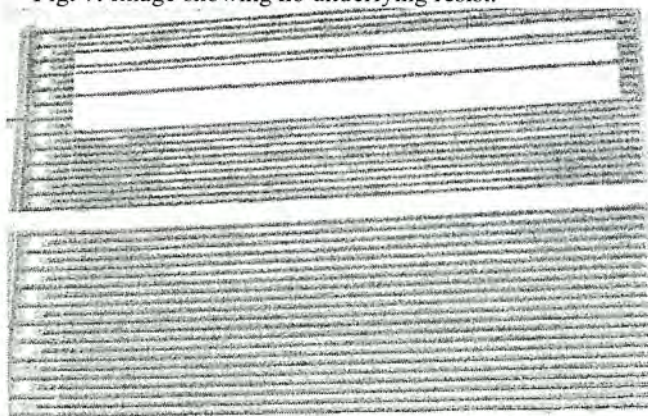


Fig. 8: Image showing some of the air bridges missing.

V. ANALYSIS

When testing the fabricated devices, none of them worked as designed. They were not able to modulate the incident light. Looking at the SEM pictures shown in Fig. 4, it can be seen that most of the 800 μm air bridge were bent down due to the internal stress while depositing aluminum. Only about 20 μm of the bridge floated on air. Mechanically, the supports were not capable of handling the load. Therefore, when tested the devices did not perform as expected. Fig. 5, that for devices of length 50 μm , the air bridge did not collapse. When testing the device they also did not perform as expected. Looking at SEM pictures in Fig. 6, for devices that were built with anchors every 80 μm , it can be seen that those devices have not collapsed either. But due to the anchors, this device would not perform as required therefore, was not tested.

An image was taken for a 50 μm device, with some of the aluminum layer being prodded, and it can be seen as shown in Fig. 7, that most of the resist had been removed. Therefore from the fabrication process, it can be seen that using the Lam 490 tool, the resist can be best removed using plasma etch. Even during the second lithography step, the HMDS prime bake, soft bake and hard bake temperatures were reduced to 100°C, in order to avoid this out-gassing problem. Acetone was not a good way to remove the resist, as there was some underlying resist in the devices. As seen from Fig. 8, some of the air bridges are inadvertently connected together.

For the 800 μm devices most of the air bridge were bent down. This led to the devices not being able to be tested. A solution to this problem would have been to change the aluminum deposition parameters such as deposition power and pressure. A situation could have been created while depositing the aluminum layer, there was tensile stress applied. This could have led to better array of air bridges.

VI. CONCLUSION

None of the devices that were fabricated performed as planned. For all 800 μm devices the air bridges were all bent down due to internal stress. A modified process, where the deposition power and pressure are changed in order to have tensile stress while depositing the aluminum layer could have been a solution for this problem. As seen from the SEM pictures, 50 – 80 μm air bridge devices were easily fabricated. It was also noted that using the LAM 480 plasma tool was the best way to remove the resist layer.

VII. ACKNOWLEDGEMENTS

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