# Process Development for an Anti-Reflective Micromechanical Modulator

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**Abstract- The purpose of this Senior Design project is to design and develop the process for an Anti-Reflective Micromechanical Modulator at RIT's facility, based on AT&T Bell Laboratories presented device, OFC '94). The device is fabricated using common semiconductor materials and is used to reflect a laser signal. There are 2 states of operation: the optically ON state, which reflects the signal, and the optically OFF state, which cancels the signal out through destructive interference. A three-layer mask process was designed on RIT's IC Layout software, the levels being the Active, Metal, and Sacrificial Evacuation areas. The process steps include 4 Lithography steps, Thermal Oxide, LPCVD Nitride, Spin On Glass, and Chemical Mechanical Planarization. Some processing issues that are dealt with are the CMP of the SOG, the photo patterning of metal on a planar surface, and the removal of the sacrificial material/freeing the membrane. The optical operation of this device is not within the scope of this project.**

## 1. INTRODUCTION

The Anti-Reflective (A-R) Membrane is an optical micromechanical device, which has two states of operation. The optically ON state reflects a laser signal. The optically OFF state, through destructive interference, cancels the signal. The anti-reflective membrane is designed to be one-quarter the signal wavelength thick, and the height of the membrane from the substrate is some multiple of one-quarter wavelength.

The device layout is not a new design. Preston designed a structure similar to the one used in this paper, in which he called "Deformable Membrane Mirror Light Modulator" (MLM) in 1968. His paper was referred to by a more recent patent from Optron Systems, who's structure was based on the MLM in 1995 (US Pat. 5471341). A competing structure was introduced by Texas Instruments as being a Digital Micro-mirrored Device (DMD) which received a patent the same year, 1995 (US Pat. 5457566). My structure is based on the device presented by AT&T Bell Labs during the 1994 Optical Fiber Communications conference, as shown in Figure 1. The potential uses for the A-R Membrane are projection television systems, optical computer systems, multispectral infrared target simulation, and optical communications, which was AT&T Bell Labs' use.

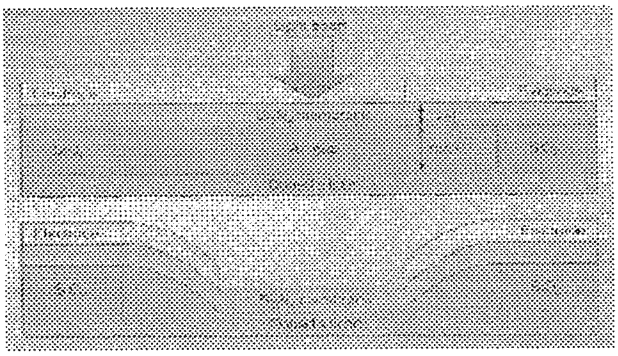

Figure 1 AT&T Bell Labs Device[1]

## 2. MASK DESIGN AND LAYOUT

Using RIT's IC Layout software, the mask was designed to have multiple structures with varying dimensions. These included two, three, and four electrode devices while varying both membrane and electrode lengths and widths. Also included in the design were simple array structures of the two-electrode design. Both membrane and electrode dimensions varied. Finally on the device, a Thermal Actuator was designed, with similar, but the realization of this device was not in the scope of this project and is left as future work.

The main two-electrode device, with labeled materials, is shown in Figure 2.

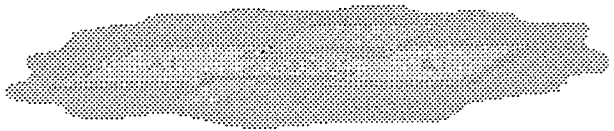

Figure 2

As an example of the varying design, the structure in Figure 2 varied in Length of membrane (from 20um to 200um), in Width of membrane (from 10um to 70 um), the width of the electrodes (from 4um to 20um) and the Over

Hang of the electrodes (from 8um to 23um). This was done similarly for the other device structures.

## 3. PROCESS DEVELOPMENT

The designed process contains three mask layers, but requires four photolithography steps (the second step is used to clear the aluminum from the alignment die for proper alignment of the metal etch layer). The process steps are as follows:

1. **p-type starting substrate**
2. **Standard RCA clean**
3. **Thermal Oxide growth** ~4000A
4. **Nitride Deposition** ~1000A -CMP barrier
5. **Photo-pattern Sacrificial Trench**
6. **Dry Etch Nitride** -$SF_6$ 50 Watt, 1min
7. **Wet Etch Oxide** -Buffered Oxide Etch
8. **Strip Resist** –Ash
9. **Spin On Glass** -Accuglass 512, 2000rpm, 1min
   -120°C hotplate, 2min
   -425°C cure, 60min, $N_2$
10. **Chemical Mechanical Polish**
    -Concentric Groove Rodel IC1000-A1
    -Bayer Levisil 100, 45%
    -6PSI, 60rpm, 1min polish +30 sec rinse
11. **Nitride Deposition** ~1000Å Membrane
12. **Aluminum Deposition** ~2500Å Electrodes
13. **Photo-pattern Metal**
14. **Wet Aluminum Etch** -Hot Phosphoric Acid ~1.5 min
15. **Strip Resist** –Ash
16. **Photo-pattern Sac. Removal Windows**
17. **Wet Etch** –Buffered Oxide Etch Sac. Material ~5min
18. **Strip Resist** –Acetone and blow dry

Because the optical operation of this device was not within the scope of this project, the trench height and membrane thicknesses are arbitrary.

The final resist strip should not involve any heat; otherwise the membrane will adhere to the substrate through stiction. Other forms of releasing the membrane need to be investigated.

## 4. PROCESS ISSUES

The most significant process issue was that of the planarization of the sacrificial material. The material first proposed for the sacrificial layer was a Low Temperature Oxide (LTO), but in order for the film to start planarizing itself during deposition, the film thickness would have to be on the order of microns, causing a deposition time of hours, and lengthened polish time. But there was a risk in choosing the SOG, as the expiration date was June '94. But this ended up begin the wisest choice due to the planarity of the material and the potential selectivity for the CMP process.

The other issue, which RIT doesn't have the capability or the equipment to tackle is that of stiction.

## 5. RESULTS AND CONCLUSIONS

The polishing results of the LTO are as shown in Figure 3. It shows the post polish data, both visual and profile, of the resulting sacrificial trench. It is clear that the next step (nitride membrane deposition) on top of a non-planar surface such as this would not result in a working device. There is ~2000Å of dishing, and as the photo shows, there is still LTO on top of the nitride CMP barrier. The polishing of this material was unsuccessful.

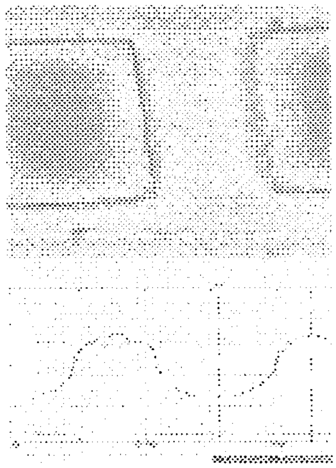

Figure 3. Top view and height profile following the CMP LTO

The following table shows the step height across the same features as in Figure 3, but the sacrificial material is Spin On Glass. This table represents the final profile heights after CMP.

Table 1 Summary Post CMP of SOG

| Device Wafer | Step Height (Å) |
|---|---|
| D22 | 165 |
| D23 | 580 |
| D24 | 215 |
| D25 | 218 |

As for device results, two devices worked. The processing issue that is holding MEMS devices such as these from working at RIT is that of stiction. Some proposed methods of avoiding stiction are (1) evaporation drying of DI water, (2) evaporation drying of methanol, two different sublimation drying techniques, or supercritical drying with $CO_2$ .

## AKNOWLEDGEMENTS

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## REFERENCES

[1] Eugene D. Jungbluth, "Micromechanical Modulators Simplifies Filter-in-the-Loop Applications", Laser Focus World, 15-16, April 1994

**Jason Neidrich**, originally from Rochester, NY, received B.S. in Microelectronic Engineering from Rochester Institute of Technology in 2000. He attained co-op experience from Rochester Institute of Technology in CMP under Dr. R. Lane, at Advanced Vision Technology, and Xerox in the Ink Jet Business Unit, CMP. He is joining Texas Instruments as a process engineer in the Digital Light Processor group in June 2000.