AFRL-SR-BL-TR-98-

0501

REPORT DOCUMENTATION

...d ...-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Final 01 Aug 97 to 30 Apr 98

4. TITLE AND SUBTITLE
SBIR-97 Enhanced process development for inteferometric Modulators

5. FUNDING NUMBERS
65502F
3005/SS

6. AUTHOR(S)
Dr Miles

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Etalon Inc
33 Hanson Street Suite 2
Boston MA 02118

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NE
110 Duncan Ave RmB115
Bolling AFB DC 20332-8050

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-97-C-0048

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVAL FOR PUBLIC RELEASED: DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The most significant accomplishment is the successful fabrication of devices from the test device mask set with brightness and contast which are improved over the 5 x 7 devices. These IMods are exhibiting the expected color response, switching clearly from green to black. Actuation voltages remain in the area of 10 to 15 volots, with response times on the order of 75 microseconds. Color uniformity is also quite good, though this has only been assessed via naked eye observation. There appear to be some charging effects which are having an impact on device pull-in and released voltages.

19980617 032

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

(48)

Phase I SBIR Progress Report # 4
Final Technical Report

SBIR Topic AF97-003

Enhanced Process Development for Interferometric Modulators

Etalon, Inc.
33 Hanson St. #2
Boston, MA 02118

Contract # F49620-97-C-0048

Principal Investigator:
Mr. Mark W. Miles

Program Manager:
Dr. Howard Schlossberg
AFOSR/NE
Directorate of Physics & Electronics
110 Duncan Ave, Room B115
Bolling AFB DC 20332-8050

Objectives

Objectives a, c, and d remain as originally stated in the contract. Objective b has been modified. Specifically, the examination of process compatibility has been broadened to consider process compatibility not only with CMOS processing, but also with LCD manufacturing capacity.

Status

Process development has now shifted to issues concerning black mask fabrication and the next generation IMod, a black and white design to be explored in the Phase II. Attempts have already been made to fabricate devices with a black mask incorporated. These were largely unsuccessful for reasons which are not clear at this stage. Device fabrication has also shifted from the 5 X 7 mask to a larger test device mask which contains 35 arrays of IMods with a variety of different geometric configurations. The success of the fabrication of these devices has provided some interesting data on etch processes. Preliminary analysis of the B&W IMod design has also occurred from a processing perspective. These results will be further discussed.

Accomplishments

The most significant accomplishment is the successful fabrication of devices from the test device mask set with brightness and contrast which are improved over the 5 X 7 devices. These IMods are exhibiting the expected color response, switching clearly from green to black. Actuation voltages remain in the area of 10 to 15 volts, with response times on the order of 75 microseconds. Color uniformity is also quite good, though this has only been assessed via naked eye observation. There appear to be some charging effects which are having an impact on device pull-in and release voltages. There are also some issues concerning localized actuation of individual IMods which are contributing to an averaging of the actuation and release times of these devices. Different portions of the membrane are observed to actuate at different voltages. Structural modifications are being considered which may mitigate both charging and averaging phenomenon.

Process Issues

Final Etch Step

The final etch step remains problematic though evidence continues to mount that water vapor incursion is the root cause. Evidence in favor of this possibility is based on an observed correlation between laboratory humidity (which is not controlled) and the quality of the etch. Higher humidity results in lower etch quality. The current system remains leaky despite efforts to improve its vacuum system and incorporate frequent pump/purge cycles during the etch sequence. Specifications for a new etch system are currently being defined. There have also been some interesting etch loading effects which have been observed. In particular, the large test device arrays etch more successfully than the smaller 5 X 7's. The reasons behind this are not understood.

Black Mask

The test device mask set also incorporates a black mask level, with the general concept being to take advantage of the IMod materials set. Depositing the IMod materials stack with an appropriately sized oxide spacer provides a very efficient black mask film which can be patterned. The active IMod array is then fabricated subsequently. Several test device wafers have been pushed through however no viable structures have been observed or, perhaps, can be observed. The color of the devices is significantly off, even before the final etch step. This suggests that either the film thicknesses are very divergent, or that there is another material in the form of an etch residue or underetched film remaining. Film thicknesses seems an unlikely candidate given the current success in depositing films with great consistency. There are, however, a number of dry etch steps which must occur in order to successfully pattern the black mask. The thickness of these films contributes significantly to the performance of the black mask layer. Consequently, if a film is not completely etched then the subsequently fabricated active IMod device may not reveal the correct color. These etch steps, even though they are based on reactive ion etching, can produce etch residues which may have an impact similar to the XeF2 etch. In general, the entire array appears dark both before and after the final etch step. The consequence of this is that it is impossible to visually confirm either a successful etch or actuation of the structures.

Next Generation IMod

B&W IMod design

The following illustration shows detail of the structure of the IMod B&W design. This device presents several challenges from a fabrication standpoint. The first is the fact that the movable membrane is actually a multilayer stack comprising films of Al, SiO2, and W. This will have an impact on the structural integrity of the structure as well as the ability to control the overall stress of the membrane. Stress control may be achieved by playing with the individual film stresses in a way which results in an approximate desired aggregate stress. What impact that will have on device performance remains to be seen and will be a significant portion of the Phase II effort.

A more immediate issue concerns the fabrication process. In particular, it has been determined during the course of the Phase I that XeF2 will etch W, at least W deposited via e-beam evaporation. This may not be true for sputtered films given the greater density of sputtered W, though the density may just lower the etch rate. The worst case scenario will require a protective film, such as SiO2, which is used in the current process. The presence of this film will have a bearing on the optical performance of the device, as well as additional structural implications.

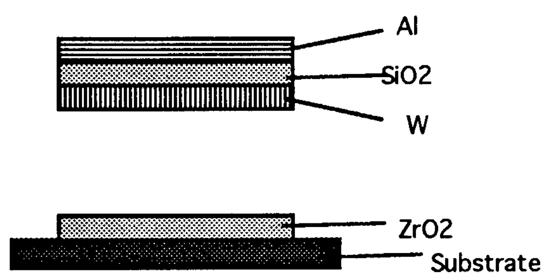

Fig. 1 Figure illustrating structural composition of the B&W IMod design.

Figure 2 illustrates the theoretical performance of the structure illustrated in figure 1. Maximum reflectivity is on the order of 60%, with minimum reflectivity below 1%. The black state occurs when the device is actuated. This design should be suitable for newspaper quality black and white displays. In figure 3, the impact of the addition of a protective oxide film is shown. Overall it can be seen that the thickness of the film is inversely related to the ultimate contrast ratio of the IMod. A thicker film results in lower reflectivity unactuated state, and a higher reflectivity in the black state.

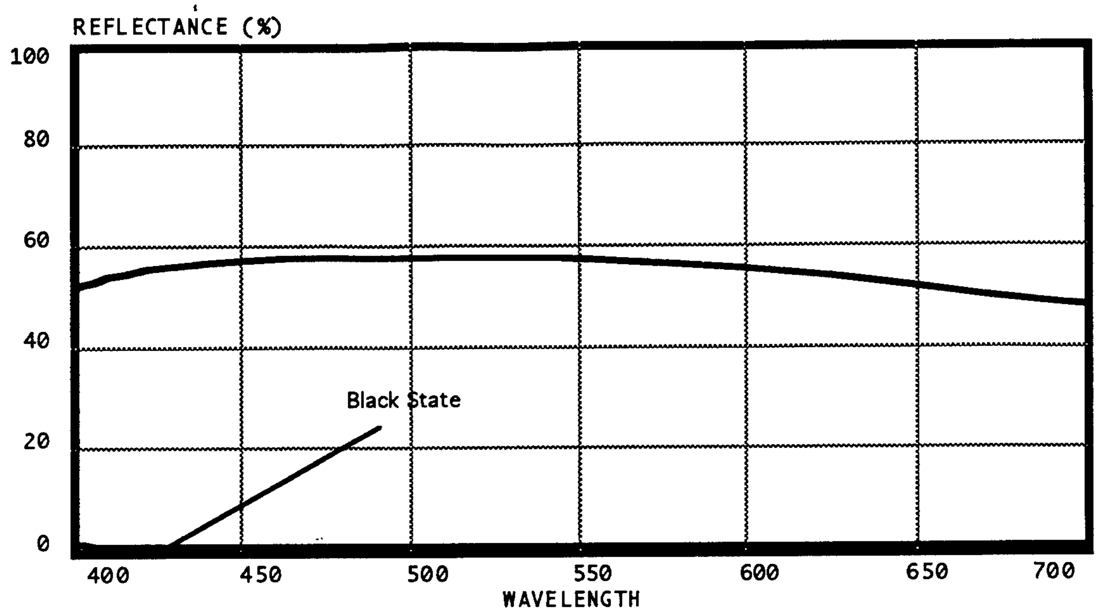

Fig. 2 Plot showing theoretical performance of B&W design. Reflectivity in the white state approaches 60%.

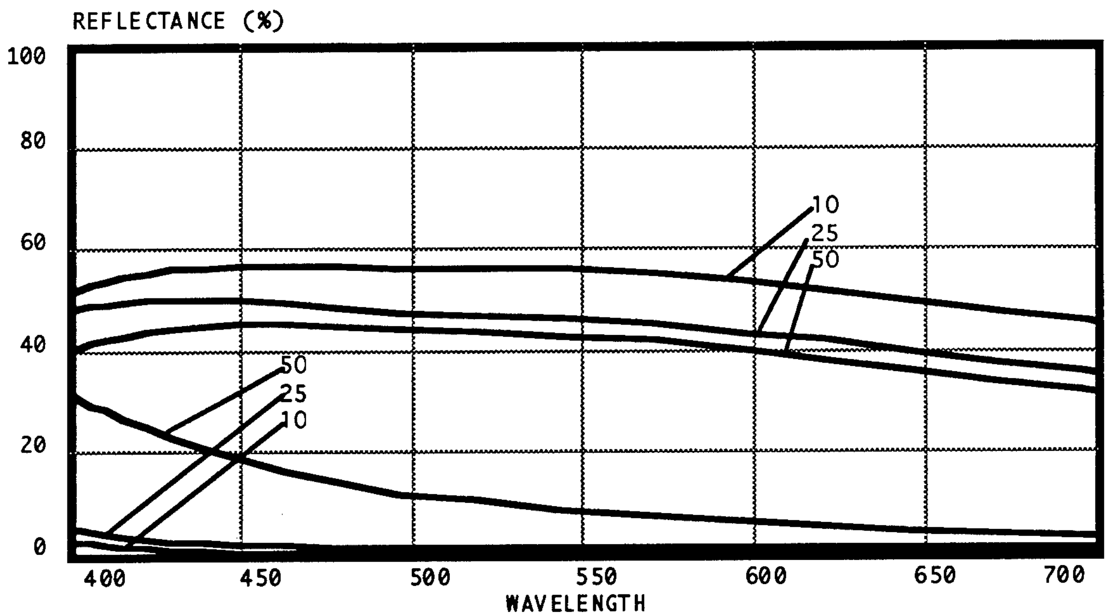

Fig. 3 Plot showing impact of protective oxide on B&W IMod performance. Plot shows effects of oxide thicknesses of 10, 25, and 50 angstroms. In general, increasing the thickness of the film reduces the contrast ratio.

Discussion and Next Steps

Fabrication of test devices with good color performance has illustrated that the final etch residue problem can be overcome with positive results. Greater success with the larger test devices vs. the 5 X 7's during the final step, has provided some interesting insights into the nature of this problem, along with greater evidence towards the influence of water vapor. An initial specification for a new etcher has been accomplished and distributed to vendors.

Failure of the first devices with a black mask seems to indicate the presence of a film or films in the form of an etch residue or underetched film. Progress is already underway to isolate the origin of this problem. Any etch residue may be eliminated by lengthening the cleaning steps required, and underetched films may be overcome by utilizing overetching wherever possible. Modeling and optical characterization will be utilized to aid in the location of the errant film.

Given that the B&W design will be the first design considered in the Phase II effort, emphasis is being placed on the susceptibility of the W to etching by XeF2. One solution to the problem is to incorporate a protective oxide layer to prevent etching of the W. This has the impact of adding an additional layer to the movable membrane, which could make it more difficult to stress balance as well as compromise the structural integrity. Optical modeling also reveals that the presence of this film impacts the ultimate performance negatively. The overall result being a reduction in the ultimate contrast ratio of the device. There maybe be an acceptable tradeoff, however, which will be determined by what the minimum required oxide film thickness is. There is also the possibility that W deposited via sputtering may exhibit significantly improved resistance to etching. This will be investigated along, and experiments will also be run to determine the minimum required thickness for a protective oxide coating.