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SWITCHABLE ZERO ORDER DIFFRACTION GRATINGS AS LIGHT
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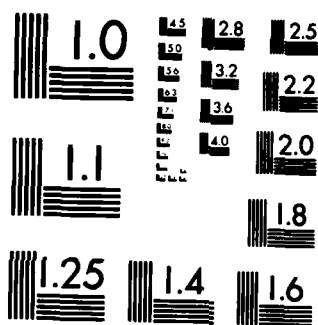
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End of the Fiscal Year Report
(1 October 1983 to 30 September 1984)

"Switchable Zero Order Diffraction
Gratings as Light Valves"

Office of Naval Research
Contract N00014-84-K-0073

Submitted by
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The aim of this project is to fabricate a light valve which operates on the principle of the cancellation of the zero order of diffraction. The light valve consists of two facing aligned phase gratings in a transparent medium. Displacing one grating with respect to the other by one-half of one grating period switches the valve from a transmitting to an absorbing state. The light valve is to be about 1-2 mm square and be mass producible into matrix addressable arrays. Arrays of this type can operate as displays or as spatial light modulators for optical signal processing.

We have chosen to fabricate the light element using polyvinylidene fluoride (PVF₂) which is a transparent piezoelectric. The gratings are embossed into the plastic and the piezoelectricity is used to produce the motion needed for switching.

Program During the Year

a) Embossing

Using techniques developed previously 3.8 μ m period, 0.25 to 1.5 μ m deep grating templates were produced. The profile in the nickel template was verified by electron microscopy to be close to square wave. These templates were then used to emboss several series of samples. For example, in one series 32 samples were pressed at temperatures of 60 and 70°C at pressures between 30,000 and 60,000 psi. Sample curling after embossing could be minimized by permitting the PVF₂ to cool in contact with the mold. The normal incidence transmission spectra of the gratings was measured. The expected $\cos^2(\pi(n-1)a/\lambda)$ dependence was observed. From the position of the minimum as a function of wavelength, λ , the depth of the grating, a , was inferred since the index n is known. Variation in depth as a function of

embossing pressure was observed. For example, gratings embossed at 67°C and 30,000 psi had a depth 0.35 μ m while those embossed at 50,000 and 60,000 psi were 0.5 μ m deep. The grating on the nickel master was measured to be 0.65 μ m $\pm$ 0.1 μ m deep. Some relaxation of the embossed grating takes place. In addition, in the deeper gratings the PVF₂ appears to shear just below the vertical grating sidewalls. The depth of the shear is about one micron. In fact, we speculate that some shear of the material appears to be needed in order to produce vertical sidewalls. Although gratings can now be produced for the purpose of demonstrating the light valve, we plan to study the embossing and to improve the process.

b) Motion Produced by Piezoelectricity

If the light valve is to be of 1 mm dimensions, then, since the piezoelectricity can produce a relative length change of about 10⁻⁴, motion of about 0.1 μ m can be expected. We need about ten times as much. A scheme for amplifying the motion has been conceived and found to work. The grating element is attached to two sets of very open chevron shaped arms. A small change in length of the arms produces a larger displacement of the center. Thus,

to fabricate these chevrons in 9 μ m

thick PVF₂ with electrodes on both sides a number of new techniques have been developed.

1. Lithography (resist spinning, exposure and development) on 9 μ m thick PVF₂ membranes, which has the consistency of "Saran Wrap". Present technology is designed for rigid wafers or glass plates.
2. Reactive-ion etching to perforate the membranes in the desired pattern.

3. Transfer of the perforated (delicate) membranes from the lithography jig to the measuring fixture.
4. Microgluing or crimping of the fixed part of the membranes to the mating surface of the measuring jig.

The first two fabrication steps have been achieved by mounting the PVF_2 sample on an aluminum substrate using diffusion pump oil. A transfer technique which depends on attaching the membrane to a frame has been tried and found to work. To attach the chevron arms to a substrate microgluing and crimping were investigated. Although crimping has been found to work, and we favor that in the long run, the current chevrons were attached by glue, and the desired motion was observed, i.e., when voltage is applied to the arms of the chevron, a 1 mm square of PVF_2 are displaced two microns. This is more than enough to operate the light valve. We are now in the process of fabricating the same structure with gratings on the two faces.

Based on these results we have submitted an abstract to the SPIE Symposium on "Advances in Display Technology" to be held January 20-25, 1985. A copy is attached.

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A Display Based on Switchable Zero Order Diffraction Grating Light Valves[†]

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A flat panel display technology has been conceived which utilizes a matrix of line addressable light valves back lighted with a partially collimated source. The basic pixel element of the display is an optical switch based on the zero order of diffraction by two facing aligned transmission phase gratings. The transmission of light is modulated by mechanically displacing one grating with respect to the other by one-half of the grating period. The color transmitted by the light valve is controlled by the grating profile.

Optical spectra of a large-scale prototype of the switchable light valve element are in good agreement with calculations according to simple diffraction theory. Technology for the construction of an optical switch of the desired size has been developed, with 85% of the area devoted to light transmission. The elements are one millimeter squares made of polyvinylidene fluoride (PVDF), a transparent, piezoelectric plastic. Gratings of nearly square wave profile with 3.8 micron period and depths from 0.6 to 1.8 microns are produced in 9 micron films of PVDF by embossing at 4000 bars and 70°C and show the expected optical transmission spectra. Mechanical displacement is produced by applying voltage to two sets of bending arms attached to either side of the movable element. The bending arms amplify motion due to piezoelectric strain. Nickel electrodes are patterned onto the PVDF film by photolithography and liftoff. Perforations around the movable element and the bending arms are etched through the film by reactive ion etching in oxygen, using patterned aluminum as a mask. Motion exceeding 2 microns has been observed, which is sufficient to operate the light valve.

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