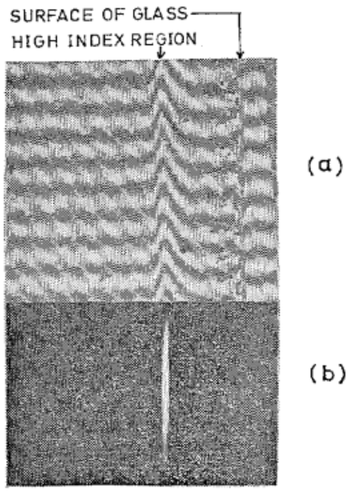

Fig. 1. (a) Refractive index profile after two-step diffusion of ions. (b) Light guiding in the same specimen, 20 mm long.

length was tested as a waveguide by illuminating one end of the high-index region directly with a He-Ne gas laser operating at 0.63 μm and viewing the opposite end with a microscope. A photograph of the end of the slab is shown in Fig. 1(b). A bright line occurs about 250 μm inside the edge corresponding to the high-index region of Fig. 1(a). The Tl^+ ion diffusion did not introduce any color centers and the transmission loss of the waveguide was estimated to be less than 0.1 dB/cm and could not be measured with short samples.

Rectangular waveguides can be formed by selective diffusion of Tl^+ ions using a thin film mask, similar to the technique for the production of electronic integrated devices. The guiding region was located beneath the surface of the substrate glass, so that the guide was easily excited directly by a Gaussian laser beam. This approach is promising as a method of producing low-loss optical integrated devices.

F.3 Embossed Integrated Optics, H. P. Weber, W. J. Tomlinson, E. A. Chandross, and R. Ulrich, *Bell Telephone Laboratories, Inc., Holmdel and Murray Hill, N. J.*

We report a number of experiments utilizing the newly developed embossing technique for the fabrication of integrated optical structures. A relief pattern in the surface of an embossing die is replicated in the surface of a substrate. Filling or overcoating the pattern with a higher refractive index material results in the desired structures. The fabrication of the embossing dies, the replication and filling techniques, and some applications of the structures will be discussed.

To fabricate the die we write a pattern into a high resolution positive photoresist (GAF Microline Photoresist PR 102). After development a thin gold coating is evaporated onto the resist and it is increased to ~3-μm thickness by electroplating. The gold layer is cemented to glass with epoxy resin and after a heat treatment the gold layer is separated from the photoresist. To replicate the pattern, the die is pressed into a thermoplastic substrate, such as polymethyl methacrylate (PMMA) or Plexiglas, at a temperature close to the softening point. An alternative process is to use the die for casting a thermally polymerizable monomer into the desired pattern. All of the described steps have very high spatial resolution. We have made many replicas of gratings having up to 2750 lines/mm and amplitudes (peak to trough) of 750 Å without any noticeable deterioration of the die.

The structures embossed or cast on the PMMA substrates were filled (for strip guides) or overcoated (for gratings). We used monomers of the methacrylate family in which polymerization can be photoinitiated at room temperature. By the use of mixtures of monomers the index of the polymer can be adjusted between 1.505 (cyclohexyl methacrylate) and 1.565 (benzyl or 2-phenylethyl methacrylate). We have measured losses in such films as low as 0.2 dB/cm at 633 nm.

In films coated over embossed grating structures we have demonstrated directional coupling in and out of the film. Calculations on coupling efficiencies as a function of index difference (film substrate), film thickness, grating periodicity, and polarization are reported. It is shown that the attenuation constants for different polarizations can differ by a factor of 5 or more; thus polarizers can be built in thin film form. Optical filters within the film, having the characteristic of low-pass and high-pass filters are also described. The possibility of making channel dropping filters for frequency multiplexed signals is emphasized. It is further shown that the fabrication of a thin-film distributed feedback laser is feasible by making use of the embossing technique.

F.4 Guiding and Control of Optical Beams in Semiconductor Epitaxial Films *(Invited),* A. Yariv, *California Institute of Technology, Pasadena, Calif. 91109.*

Observation of light guiding in thin dielectric films was first made in 1961 in optical fibers by Snitzer and Osterberg[1] and by Kapany and Burke[2] and in p-n junctions in 1963 by Bond, Cohen, Leite, and Yariv.[3,4] Shubert and Harris[5] in 1968 and Miller[6] recognized the importance of structures incorporating thin films for integrated data processors.

This talk is devoted primarily to what one may call "active integrated optics," i.e., the performance of a variety of active tasks including light generation, modulation, switching, and correlation in thin-film circuits. This particular area of activity traces its beginning to experiments by Nelson and Rinehart[7] in 1964 in which the guiding of light in GaP p-n junctions was accompanied by electrooptic modulation. In 1965 we started at Caltech on experiments designed to demonstrate guiding and electrooptic switching in thin films. The demonstration of these effects[8,9] had to wait until 1970 for the maturation of the epitaxial film technology. Work on switching and mode coupling in thin films by sound waves has been reported recently by two IBM groups.[10,11]

The ability to design active thin-film components requires a separate understanding of the electromagnetic properties of the modes that can propagate in thin films and their interplay with the photoelastic and electrooptic phenomena used in active coupling and switching.

This discussion reviews the theoretical background of the different building-block disciplines with special emphasis on the theoretical aspects of combining them to perform various optical functions. The general coupled mode theory is used to describe the following special cases: 1) mode coupling; 2) phase and amplitude modulation; 3) Bragg diffraction; 4) cutoff switching; and 5) field penetration control.

We will review the recent experimental work at Caltech and specifically describe experiments involving electrooptic beam control, voltage controlled cutoff, diffraction grating fabrication, and waveguide fabrication by proton implantation, all in GaAs.

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F.5 Thin-Film Optical Directional Coupler, A. Ihaya, H. Furuta, and H. Noda, *Research Laboratory, Fujitsu Laboratories Ltd., Kawasakichi, Japan.*

The coupling between parallel guiding rods of slightly different sizes and dielec-