2:00pm - 2:30pm (Invited)
WC2

MEMS Applications in Optical Systems

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Introduction

We describe progress in the development of basic micro-opto-mechanical; components which are compatible with MEMS and integrated circuit processing processing. Devices which have been developed include polygon and diffraction grating scanners, tunable laser diodes, tunable IR filters, and optical waveguides.

Polygon Microscanners

A planar view of a polysilicon microscanner consisting of a hollow, nickel plated polygon reflector on the rotor of an electrostatic drive micromotor is shown in Figure 1. The nickel plated polygon reflector is approximately 175μm in diameter, 20μm tall, and 10μm thick. The diameter of the micromotor rotor is 500μm. These dimensions are typical of microscanners produced by surface micromachining. The 20μm vertical height of the nickel reflector is typical of elements that can be produced by our electroless nickel plating process. We have produced micromotor scanners similar to Figure 1 with diameters from 250 to 1000μm although the larger micromotors do not operate reliably after release.

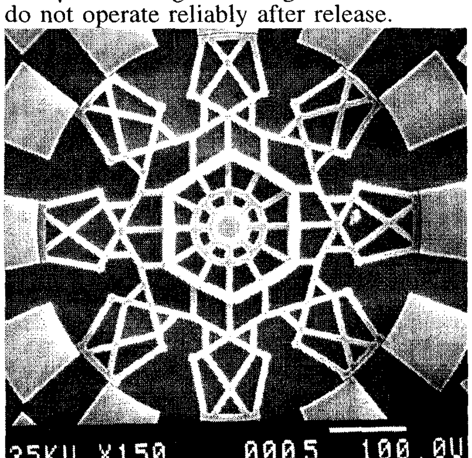

Figure 1. SEM photo of a rotating polygon optical microscanner on a 500μm diameter salient-pole micromotor.

Diffraction Grating Microscanners

An optical microscanner which consists of a diffraction gratings on the rotor of an electrostatic polysilicon micromotor is shown in Figure 2. The diffraction gratings are produced by chemical etching, then chemical-mechanically polished (CMP) to reduce the average surface roughness, improving the optical efficiency of the gratings. This process has been used to produce diffraction grating microscanners. These devices require thick (e.g., 5.5 μm) polysilicon rotors to provide sufficient mechanical stiffness and to prevent out-of-plane warping of large area rotors.

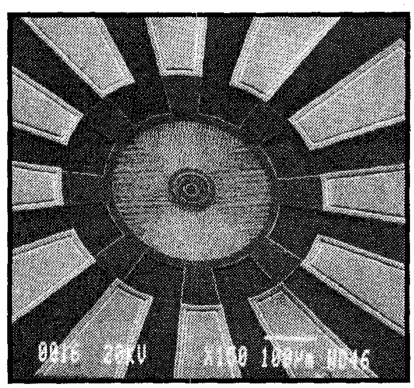

Figure 2. SEM photo of a rotating diffraction grating microscanner. The motor is a 500-μm diameter salient-pole side-drive micromotor with polished rotor/stator polysilicon and pyramidal grating element of 1.8 μm period.

Laser Diode Tuner

A (111) sidewall of a silicon cantilever beam has been developed as a tunable micromirror for a tunable laser diode. The micromirror beam was fabricated by anisotropic etching of (110) silicon in conjunction with silicon-to-glass bonding. Electrodes located on either side of the beam provide the electrostatic force that deflects the beam; the (111) sidewall of the cantilever beam functions as the external mirror of an optical cavity. Mechanical stops limit the lateral deflection of the beam, preventing electrical shorting to the electrodes. Figure 3 is an SEM image of the final device. The beam is about 1.7 mm long, 8 μm wide, and 130 μm high. The external cavity length, (the gap between the beam sidewall and the laser diode facet) is about 10 μm. The laser diode is a gain guide type with planar stripe; the active layer is an AlGaAs multiquantum well structure. The cavity length of the laser diode is about 340 μm.

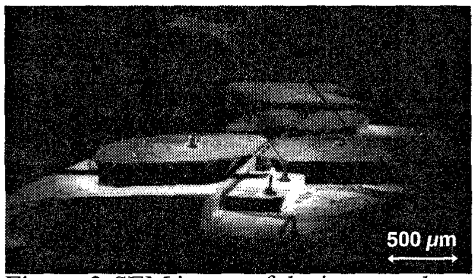

Figure 3. SEM image of the integrated laser diode and micromirror.

Tunable Optical Filters

Many optical devices require specialized optical coatings, for high reflectivity dielectric reflectors and for multi-layer anti-reflection coatings. Our approach to process integration is to do all microlithographic processing prior to any dielectric coating keeping the processes separate. We use shadow masking to pattern the optical reflective coatings on a micromachined device DSP (double sided polished) silicon wafer. We are constructing a tunable IR filter by bonding two DSP wafers with multilayer dielectric reflective optical coatings (of ZnSe and ThF_4) together to form an optical etalon. We use a KOH etched shadow mask to pattern precise thicknesses of the dielectric films used to produce the reflective coatings to maintain strict tolerances on the spacing between the reflective coatings and the parallelism of the optical surfaces. Additional depositions of the dielectric materials can be used to achieve the required spacing between the optical reflective coatings. We are currently investigating how to bond the micromachined, optically coated surfaces together. The most attractive approach appears to be a patterned evaporative coating of a low melting point metal to act as a bonding layer. Figure 4 schematically shows a $ZnSe/ThF_4$ tunable infrared filter.

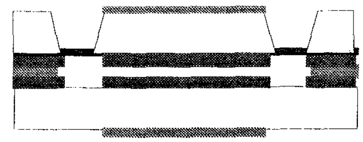

Figure 4. Tunable IR filter using evaporative coated spacers.

Both wafers are coated with reflective coating, note the reflective coating is also deposited in the spacer region. A subsequent evaporative deposition places material in the spacer region. A antireflective coating may be deposited on the backsides. All deposition is via shadow masks. The wafers may then be brought into contact as shown. Not shown are additional alignment and electrode contact patterning processing steps on both wafers.

Silicon Waveguides

We have fabricated all-silicon rib optical waveguides and U-groove alignment structures on (110) silicon substrates. Such all-silicon waveguides are compatible with our micromachining processing and are necessary components for MEMS based optical fiber devices. Rib waveguides consisting of 6.7 μm tall by 5-15 μm wide ribs have been RIE etched in lightly-doped epitaxial silicon layers deposited on heavily doped silicon substrates. Ultrasonic etching was used to decrease the roughness of etched structures. Experimental measurements of these devices at 1550 nm indicates that the waveguides are single mode. The optical loss was measured to be as low as 1.68 dB/cm.

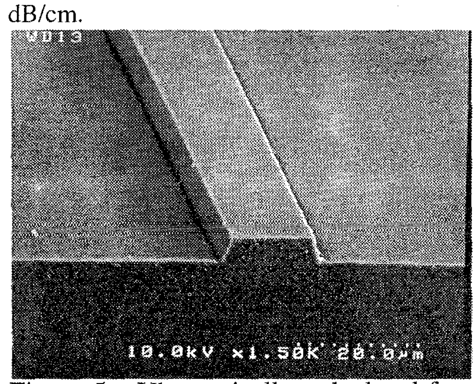

Figure 5. Ultrasonically etched end-face of a rib waveguide with a rib height of 6.7μm, a base width of 15.5μm and an etch angle of 83.6°.