A Waveguide on the Oxidized Porous Silicon for the Robust Alignment in the Silicon Optical Bench

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A V-grooved waveguide structure is proposed and fabricated for the passive alignment of the assembly of the silicon optical bench(SiOB). Its waveguide portion is polymer cured and saw-cut, and the optical characteristics were investigated.

***Introduction*:** The optical fiber module is a key technology for the high speed and broadband communication. But the expensive manufacturing cost is the barrier for the growing markets. Even though the passive alignment techniques are introduced for this breakthrough, the process requirements are usually very tight, less than 1 um. And it is very sensitive and difficult to control the etching profile and the optical module assembly. Polymer waveguides on V-grooves[1] using needle dispensing are not adequate for the fine shape of the waveguide and also for the single mode guiding. Another waveguide uses selectively confined dual Oxidized Porous Silicon(OPS) layers[2], but still have the alignment accuracy problem for the module assembly.
Here we proposed a structure with V-channel thick oxide layer and the photo-definable polymer core. The wave-guide has very thick oxide cladding and

***Design*:** Fig.1 shows the schematic of the proposed SiOB. It composed of two V-grooves of OPS of different dimensions, and the core layer of the waveguide. OPS thickness is more than 10 um. The underlying OPS makes the lower cladding of the waveguide and can be made stress free on silicon up to 40 um thick. The V-grooves for the fiber and the waveguide channel are easily and accurately aligned by making those patterns on the same mask layer and by the same KOH aniso-tropic etching process.

To compensate the volumic shrinkage of OPS materials, the initial elevation of the fiber core should be 1 um above the surface, and so width of the grooves be matched to its elevation. In this design, the width of the fiber groove is in the range of 149~155 um. The wave-guide structure is similar to the single mode rib wave-guide[3]. The core widths are various in the range of 10~20 um to make it compatible to light output from the single mode fiber.

***Experiment*:** A 0.1 um silicon nitride(SiN_3) was deposited by LPCVD method on p-type (100) silicon wafer.(rho = 6-10 ohm cm) This etching mask was patterned and etched by usual photolithography and RIE processes. Then the substrate was etched in KOH(33%) aqueous solution. The etching rate was 0.7 um at 75ºC. The final etching depth of the U-groove for the fiber channel was 75 um and those of waveguide channels were 2.8 ~ 14 um for various 4 ~ 20 um widths. After the removal of the masking layer, the anodization and the oxidation of the porous silicon layer were processed with the general SOPS process[4]. The thickness of this oxidized porous silicon(OPS) layer was about 10 um, while the channel widening due to the OPS volume shrinkage was about 2 um per each side. Then, the core layer of the waveguide was patterned with photo-Bis-benzocyclobutene(BCB) and cured 1 hour at 250°C. By using photo-BCB, the residue in the deep V-grooves can be easily removed. The thickness of BCB after curing is 4.5 um on the plain surface and the fallen is about 1.4 ~ 5.6 um at the center of the waveguide channels. With the double BCB coating of 8 um, the fallen becomes about 1.2 um.
For the evaluation of the waveguide, the wafer is saw-cut at the inlet of the waveguide.

***Results*:** The SiOB is loaded on a stage, which has the 3 direction control and two axis rotation capabilities. The light, of 632.8 nm laser beam, coupled from the fiber is guided thru the channel, and reflected at the mirror. The reflected field pattern is captured by microscope and CCD camera.
Fig. 2 shows a part of the waveguides fabricated. Fig.3 shows the beam pattern from 24 um wide channel, and Fig. 4 is the scanned beam profile.. The 3dB margin for the lateral misalignment was measured as of about 15 um .

The loss of the overall coupling is more than 20 dB. It seems to be due to the rough surface of the saw-cut waveguide front and the dielectric interface mirror on (111) surface. A dramatic improvement can be achieved by doing dry etching of the polymer waveguide inlet to get the smooth surface and the coating of the reflection metal on the (111) mirror.

References

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Fig.1 Schematic of SiOB

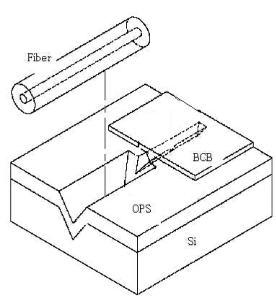

Fig.2 Fabricated SiOB

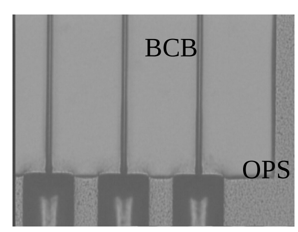

Fig.3 Reflected Beam Pattern From SiOB Waveguide

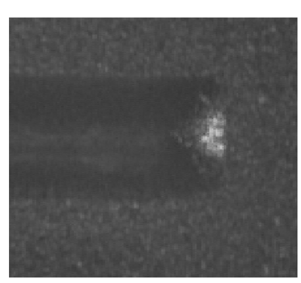

Fig.4 Scanned Beam Profile