VERTICAL 1.3μm OPTICAL MODULATOR IN SILICON-ON-INSULATOR

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There have been some efforts trying to make active optoelectronic devices, including modulators and switches, on silicon substrates using free-carrier effects[1-2]. Here we report a new optical intensity modulator at 1.3μm which utilizes a Fabry-Perot resonant cavity made possible by silicon-on-insulator technology to achieve a high modulation depth.

The schematic diagram of the device structure is shown in Figure 1. It is essentially made of a Fabry-Perot cavity and a p-i-n diode phase modulator placed inside the cavity. The 1.3μm light comes in from the top, bouncing back-and-forth inside the Fabry-Perot cavity, partially reflected back, and partially transmitted through. At resonance, the reflectance is minimized. Forward biasing the p-i-n diode modulates the phase of the laser light inside the cavity and shifts the resonance of the FP cavity to convert the phase modulation to intensity modulation. Figure 2 shows calculated reflectance from this device structure as function of refractive index of silicon layers.

Fabrication started with a SIMOX wafer having a buried oxide layer of 0.2μm thick. The oxide thickness was chosen to optimize the reflectance at 1.3μm. First, a 2μm heavily doped n-type layer was grown, followed by a 3.8μm lightly doped n-type layer and a 0.9μm heavily doped p-type layer. The doping level in the three layers were $1.1\times10^{19}/cm^3$, $1.0\times10^{16}/cm^3$, and $1.2\times10^{20}/cm^3$, respectively. Then, the diode mesa was defined using reactive ion etching. After growth of 0.22μm thermal oxide, 1000Å thick silicon was evaporated and annealed to form a high reflectance surface for high Q FP cavity. A second reactive ion etching step was used to define the polysilicon window. Finally, contact windows are opened, and aluminum metalization completed the process. Simulations show that this should produce a cavity with a free spectrum range of 350Å and passband of 50Å.

To test the device, a 1.3μm diode laser was used as light source. A cleaved single mode fiber pigtail was positioned directly above the device for both input and output coupling. The reflected signal was picked up by a directional coupler, and detected by an IR photodiode. The reflected photocurrent signal was amplified using an current amplifier and display on an oscilloscope. An attenuator was placed between the laser diode and directional coupler to reduce feedback which might cause instability in the source laser. Plotted in Figure 3 is reflected optical signal versus electrical driving level at low frequency, and Figure 4 shows the response to a low frequency triangular wave. A modulation depth of 40% was achieved, and was limited by the linewidth of laser source.

High frequency data as well as wavelength response will be presented. Structure design variations and theoretical ultimate performance of this type devices will also be discussed. The authors would like to thank R. Sundaresan of T.I. for supplying the SIMOX wafer used in this study.

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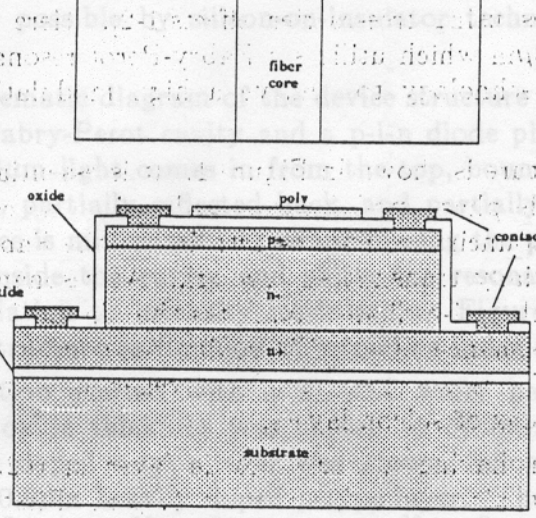

Figure 1. Schematic diagram of the device structure

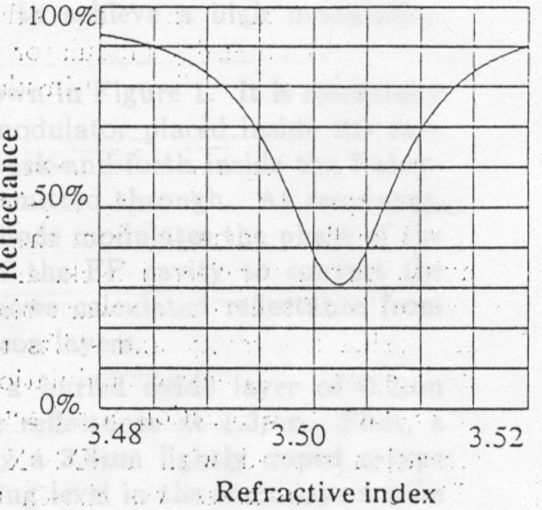

Figure 2. Calculated reflectance of device structure as a function of silicon refractive index.

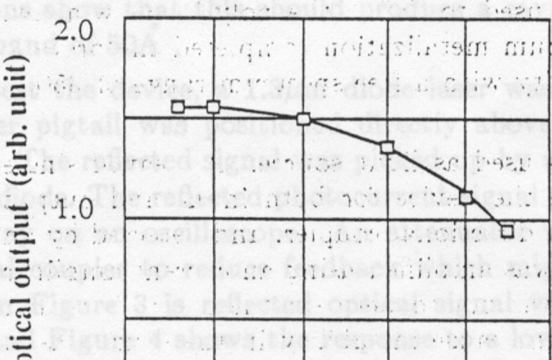

Figure 3. Measured optical output as a function of driving current density.

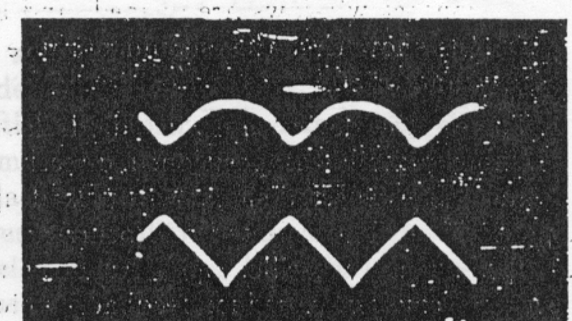

Figure 4. Lower trace is the triangular driving signal. Upper trace shows the modulated optical signal.