Propagation loss of amorphous silicon optical waveguides at the 0.8 m-wavelength range

Propagation Loss of Amorphous Silicon Optical Waveguides at the 0.8 μm-Wavelength Range

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***Abstract*-We fabricated optical waveguides using amorphous silicon deposited by catalytic chemical vapor deposition method. The waveguides were fabricated by photolithography and wet chemical etching. The propagation loss of 15 dB/cm at 830 nm was measured.**

***Index Terms*-Amorphous silicon, optical waveguides, silicon photonics, optoelectronics integrated circuit, Cat-CVD**

I. INTRODUCTION

Recently, the operating speeds of large-scale integrated (LSI) circuits have been nearing the limit where the resistance and capacitance of global electrical interconnects are becoming bottleneck. An optical interconnection instead of an electric connection on LSI is proposed to solve this problem [1]. Especially, a crystalline silicon (*c*-Si) optical waveguide have been studied intensively for optical interconnection at the 1.55 μm-wavelength range. The active device at this wavelength needs to introduce compound semiconductor such as GaInAs and AlInAs in place of *c*-Si. These materials were difficult to grow epitaxially on Si substrate because of the lattice mismatch. A wafer bonding technique as one of the approaches to integrate on Si-LSI was reported [2], [3].

On the other hand, *c*-Si can be used as the active device such as a photodetector at 0.8 μm-wavelength range. We fabricated the *c*-Si avalanche photodiode by 0.18 μm-CMOS standard processes [4]. The device realized a bandwidth of more than 1 GHz at 830 nm. However, *c*-Si is unsuitable as the waveguide at the 0.8 μm-wavelength range due to absorption at this wavelength. SiON was proposed as a waveguide material on a Si substrate at this wavelength [5]. We propose the use of amorphous silicon (*a*-Si) as the waveguide material for the 0.8 μm-wavelength range because a bandgap energy of *a*-Si is about 1.4 eV-1.8 eV. Low-loss *a*-Si waveguides for the 1.55 μm-wavelength propagation have been reported [6]-[8]. *A*-Si has possibility for realizing low loss waveguides at the 0.8 μm-wavelength. Moreover, *a*-Si is highly compatible with CMOS processes and so an *a*-Si waveguide can be integrated with a *c*-Si photodetector without the need for wafer bonding. As above, it is promising for the realization of an all-Si optoelectronic integrated circuit.

In this study, *a*-Si waveguides were fabricated by photolithography and wet chemical etching, and their propagation loss was measured at 830 nm.

II. FABRICATION OF *A*-SI WAVEGUIDE

An *a*-Si film was deposited by catalytic chemical vapor deposition (Cat-CVD) method [9]. The method has an important advantage as a plasma-less deposition technique, avoiding plasma- or charge-induced damage in the films.

The optical transmittance of the *a*-Si film (1.3 μm-thick) was measured using a white-light source and an optical CCD spectrometer. The incident white light was input normal to the

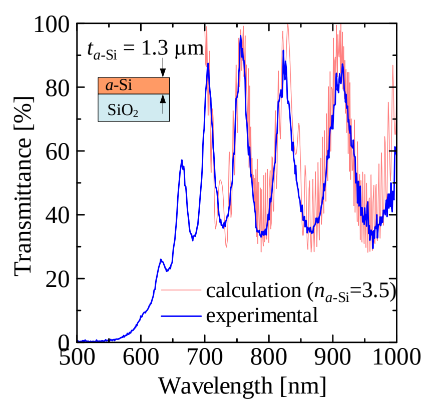

Fig. 1. Wavelength dependence of transmittance.

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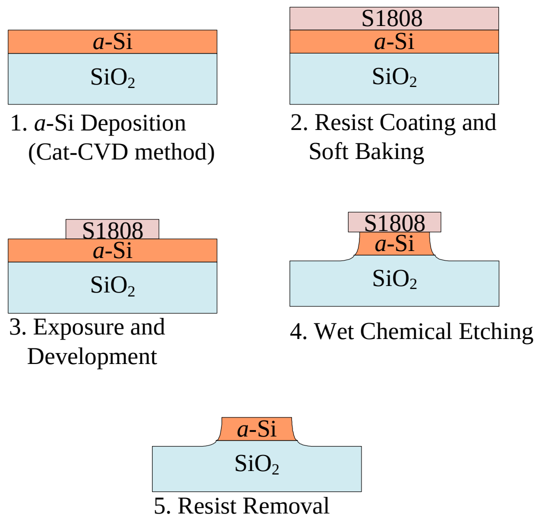

Fig. 2. Overview of the fabrication process

a-Si surface. The wavelength dependence of the optical transmittance is shown in Fig. 1. The fluctuation of the spectrum is due to a Fabry-Perot oscillation in *a*-Si film. The calculation result by transfer matrix method is also shown in Fig. 1. The calculated oscillation is agreement with experimental result at the refractive index of 3.5. *A*-Si can be used as a core layer of the 0.8 µm-wavelength propagation system.

A-Si optical waveguides were fabricated by photolithography and wet chemical etching. An overview of the fabrication process is shown in Fig. 2. The 1.3 µm-thick *a*-Si layer was deposited by Cat-CVD method. The photoresist (SHIPLEY S1808) was coated by spin coating and then the waveguide pattern was exposed to UV lithography by the contact exposure method. After removing the oxidized Si surface by HF, the *a*-Si layer and a upper side of the SiO_2 substrate was etched by $HF:HNO_3:CH_3COOH$=4:1:10 solution for transferred the waveguide patterns to the *a*-Si film. The waveguide size was

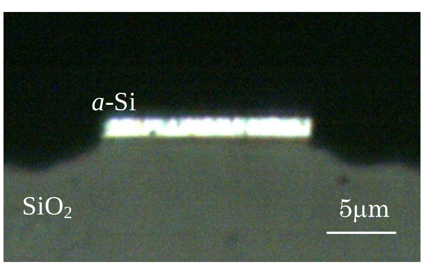

Fig. 3. Cross-sectional image of the *a*-Si optical waveguide

15µm-wide and 1.3µm-thick. A facet of the waveguide was formed by cleaving. The cross-sectional optical microscope image of the waveguide is shown in Fig. 3. The mesa-structure was obtained.

III. Results And Discussions

Fig. 4. shows the measurement system of the propagation loss. The fabricated waveguides were characterized for propagation loss by coupling in light from a laser source at 830 nm and the output from the waveguide is measured with an optical power meter. Single-mode lensed optical fibers were used for input and output coupling. This setup has no polarization control. A scattered propagation light from the surface of the optical waveguide was observed to align the lensed fiber with the waveguides. The transmitted power through different lengths of the waveguides was measured.

Fig. 5. shows the measured optical power for various waveguide lengths at the wavelength of 830 nm. The

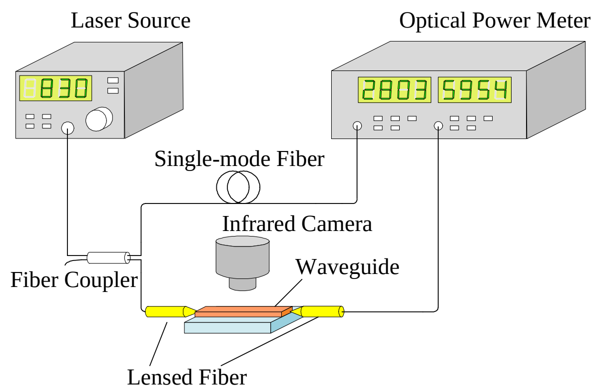

Fig. 4. Propagation loss measurement system

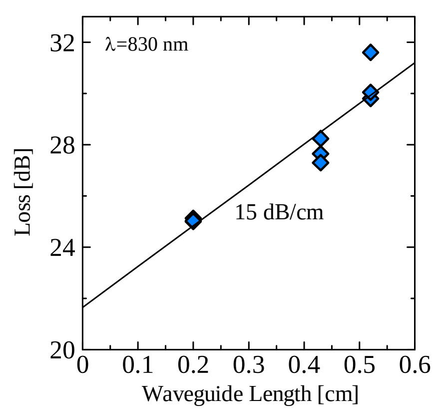

Fig. 5. Propagation loss of *a*-Si waveguides

propagation loss was obtained by linear regression of the output power versus the length of the waveguides. The propagation loss of 15 dB/cm and the coupling loss of 20 dB were measured. This result is a very promising for realization of all-silicon optical integrated circuit at the 0.8 μm-wavelength range.

IV. CONCLUSIONS

We fabricated the *a*-Si optical waveguide using photolithography and wet chemical etching. The propagation loss measurement shows the waveguide loss of 15 dB/cm and the coupling loss of 20 dB at 830nm.

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