Light Propagation Properties of Si Waveguides after Removing III-V Layer on a III-V/SOI Wafer Fabricated by Plasma Activated Bonding

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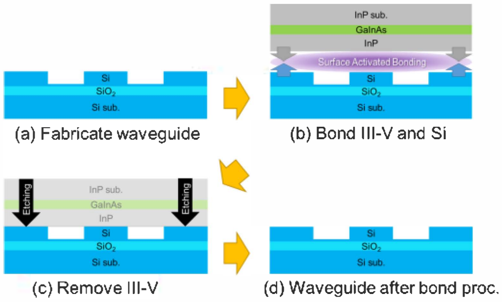
***Abstract*— Qualities of Si waveguides after III-V/Si direct bonding process was evaluated, and propagation loss of 4.0 dB/cm was achieved, which is equivalent to the value of waveguides not including direct bonding process.**

I. INTRODUCTION

IN order to realize III-V/Si photonic integrated circuits (PICs), several bonding techniques have been proposed [1-2]. A semiconductor-semiconductor direct bonding, not inserting middle layer such as SiO_2 or BCB, is an ideal method for good optical coupling between a III-V active layer and a Si waveguide. We proposed to introduce N_2 plasma-activated-bonding (PAB) technique for realizing III-V/Si PICs[3]. However, an increase of scattering and absorption losses in the Si waveguides after removing III-V layers in unwanted regions have been concerned. In this paper, we report the propagation loss of Si waveguides by different etching methods to remove the III-V layers. The propagation loss of 4.0 dB/cm, which is equivalent to the loss without bonding was obtained by the wet etching.

II. FABRICATION PROCESS

Figure 1 shows the schematics of the fabrication process. On a silicon-on-insulator (SOI) substrate with 220-nm-thick top-Si, 500-nm-wide and 190-nm-height Si-rib-waveguides were formed by EB lithography and inductively-coupled-plasma reactive-ion-etching system (Fig.1(a)). On the patterned SOI, a III-V wafer, consisting of 100-nm undoped-GaInAs etching stop layer and 300-nm undoped-InP epitaxially grown on an InP substrate, was bonded by N_2-PAB (Fig.1(b)). Then, InP substrate and GaInAs layer were selectively etched by HCl and H_2SO_4:H_2O_2:H_2O. After this, as the methods to remove the remaining InP layer, 2 different etching methods, i.e. HCl wet etching and CH_4/H_2 dry etching, were carried out on each wafer (Fig.1(c)). Finally, 1.0-µm SiO_2 upper cladding was deposited by PECVD after cleaning the surface by BHF.



(a) Fabricate waveguide (b) Bond III-V and Si

(c) Remove III-V (d) Waveguide after bond proc.

Fig. 1. Schematics of fabrication process.

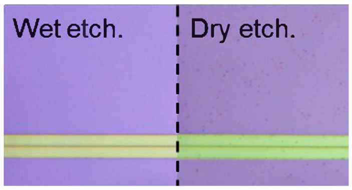


Fig. 2. Surfaces after wet etching and dry etching.

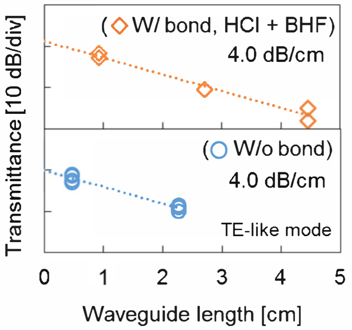


Fig. 3. Propagation characteristics.

III. RESULTS

Figure 2 shows microscopic top views of the Si waveguides after the wet/dry etching. Figure 3 shows the length dependence of the transmitted light power of the Si waveguides with and without bonding process. As shown in the right side of Fig. 2, some dirts were not removed sufficiently after dry etching, therefore, the propagation loss was so high and the output power from the Si waveguides was below measurement limit. By X-ray photoelectron spectroscopy, we have confirmed the remained dirts are mainly In-O. On the other hand, the III-V layers were removed almost completely after wet etching, so that low propagation loss of 4.0-dB/cm was obtained. This value is equivalent to the propagation loss of waveguides without bonding process.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Numbers #24246061, #25709026, #25420321, #13J08096, #14J02327 and the New Energy and Industrial Technology Development Organization (NEDO).

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978-1-4799-5261-8/14/$31.00 ©2014 IEEE