Characterization of Integrated Silicon Waveguide Devices

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Introduction
In the realization of submicron silicon waveguides, the effect of scattering loss caused by sidewall roughness greatly limits the use of these devices in integrated optical circuits [1]. The goal of this project is to investigate sidewall roughness smoothing by thermal oxidation and post-oxidation anneal aimed at reducing propagation loss in silicon waveguides.

Fabrication and Oxidation
The waveguides were fabricated on a silicon-on-insulator (SOI) wafer with a 220nm thick silicon guiding layer on a 2000nm thick buried oxide layer. The wafers were patterned by electron beam lithography and inductively coupled plasma (ICP) reactive ion etching (RIE), with an SF6/CF4 chemistry [2]. Deep etched waveguides with width varying between 0.3 to 1 µm were fabricated. The sample waveguide was covered with a PMMA buffer layer for protection. The propagation losses of the waveguides were characterized with and without the PMMA layer. The sample later went through a dry oxidation run at 950 °C for 1 min 20 sec with O2, leading to growth of ~3 nm thickness of oxide and post-oxidation anneal at 350 °C for 15 min in forming gas, with further passivation with hydrogen. Losses were subsequently measured.

Methodology

Results
The results of the simulations and experimental measurements are presented.

Table 1 Comparison of propagation loss with and without PMMA Layer

<table>
<thead>
<tr>
<th>Width (nm)</th>
<th>Propagation loss in dB/cm with PMMA</th>
<th>Propagation loss in dB/cm without PMMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>3.6 ± 0.9</td>
<td>4.9 ± 1.9</td>
</tr>
<tr>
<td>650</td>
<td>3.1 ± 1.0</td>
<td>3.5 ± 0.9</td>
</tr>
</tbody>
</table>

Fig 2 Effective index versus waveguide width for fundamental mode and second order mode for TE polarization.

Fig 3 Propagation loss versus width before oxidation

Fig 4 Propagation loss versus width after oxidation

Fig 5 Comparison of loss before and after oxidation

Fig 6 Propagation loss versus waveguide width. Inset: Modal profile of 0.45 and 1 µm width waveguide

Conclusions
The waveguide exhibits single mode behavior for widths less than 0.6 µm. Narrow waveguides have higher loss due to stronger interaction with side wall roughness and loss decreases with increase waveguide width. Finally, lower losses is also reported in the presence of PMMA layer but there was no significant changes after the oxidation process. However, we were able to preserve the integrity of the waveguide after thermal oxidation and remain optimistic about achieving a remarkable reduction in loss with repeated efforts.

References

Acknowledgements
L. Merigg, M. Strain, M. Mirza and V. Pusino