Silica High-Mesa Waveguide for Compact Infrared Sensing System

陳, 嬌

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The demand for a compact health-check system that can perform routine health-care checks has increased recently. Among many diagnostics methods, breath-content analysis is one of the candidates for daily health-care, as it contains various disease-markers and is non-invasive to human-beings. One of the attractive tools for breath-content analysis is infrared spectroscopy owing to its superior capability in ppm-order sensitivity of various kinds of breath contents. To build a compact breath-sensing system, the gas cell is one of the significantly challenging components to be realized, since the length of a regular gas cell reaches a meter-long optical path length. The compact breath-sensing system that utilizes photonic integrated circuits, such as hollow structure, slot structure, with infrared spectroscopy has been widely researched considering the capability of realizing a small radius of curvature, which is helpful for integrating meter-long optical path length into a compact area. High-mesa waveguide is attractive for its potential of being utilized for infrared absorption, where the evanescent field comes out of its solid core and profiles an optical portion out of the solid waveguide. One critical issue is its propagation loss which limits the sensing capability. In this research, we studied the scheme of scattering loss which is the main cause of loss for SOI structure. To get lower propagation loss, we proposed silica high-mesa waveguide and extremely low loss of 0.02 dB/cm has been achieved. One of the issues for silica structure lies in its low portion of the optical field-profile out of the waveguide. To get rid of this problem, we have proposed multiple slot silica high-mesa waveguide. For a quadruple slot silica high-mesa waveguide, a high portion of optical field profiles out of the waveguide of 20.6% has been achieved, and a low scattering loss of 0.06 dB/cm has been confirmed theoretically as well.

In this thesis, the research background and the purpose have been explained in Chapter 1. Breath content detection for easy medical health check-up has been proposed using infrared absorption sensing. Optical waveguide structure for infrared absorption sensing has been proposed and exploited. The estimated required propagation loss criteria have been clarified as well.

In chapter 2, the propagation loss category has been discussed. The propagation loss can be generally
attributed to three different mechanisms: scattering losses, radiation losses and absorption losses. For further classification, the scattering losses can be divided into volume scattering and surface scattering; radiation losses can be divided into radiation towards the substrate and the radiation from the waveguide bent; absorption losses can be divided into interband absorption and free carrier absorption. Some methods to get low propagation loss have also been discussed in this chapter as well.

In chapter 3, to realize lower propagation loss than SOI structure, silica high-mesa structure is proposed for infrared sensing. Setting under cladding height larger than 5 μm is proposed to suppress the radiation loss. As a result, an extremely low propagation loss of 0.02 dB/cm (@ w = 2.3 μm, λ = 1550 nm) has been achieved.

In chapter 4, the multiple-slot silica high-mesa waveguide structure is proposed. A high portion of 20.3% optical field profiles out of the waveguide has been achieved by quadruple silica high-mesa waveguide structure. Low scattering loss of 0.06 dB/cm has been confirmed theoretically as well.

In Chapter 5, the above results have been summarized and clarified about the future view of the proposed waveguide structure.