論文 / 著書情報
Article / Book Information

題目(和文)	ガラスブローイング法によるテルライトガラス超薄膜の作製と光学基板への直接接合
Title(English)	Fabrication of ultrathin tellurite glass film on a substrate by using a combination of glass blowing and direct bonding techniques
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	物質科学　　　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（Philosophy）
学生氏名： Student's Name	鄭　瑞杰	指導教員（主）： Academic Supervisor(main)	矢野　哲司
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The increasing amount of data transfer through the internet has greatly required the improvement and innovation of devices with 3D integrated optical circuits. Moreover, these devices must be reliable and efficiently coupled to other devices. One important device is the planar tapered waveguide, which can be efficiently coupled to an optical resonator for transferring optical signals with definite wavelengths. Additionally, materials with high refractive index are favored for compact optical circuits. Nanometer or submicrometer-scale planar waveguides are anticipated as built-in optical components of optical circuits.

Tellurite glass is an ideal transparent material with excellent optical characteristics, including a high refractive index (>2), ultra-low optical loss in the mid-infrared (IR) region, high nonlinear refractive indices, and low phonon energy. Especially, tellurite glasses exhibit low absorption in the spectral region beyond 2.5 μm. The physical properties of tellurite glasses have also been studied for their feasibility for fiber drawing and rare-earth doping. A tellurite glass fiber with a loss less than 1 dB/m loss was fabricated. The results of these studies indicate that tellurite, rather than silicate glass, can be fabricated as low-loss infrared optical waveguides.

In the 3D integrated optical circuits, tellurite glass is used as core and silicate glass is working as cladding in order to guide light signal though waveguide by the difference of refractive index. The glass film bonding on optical substrates, including silica, silicate glasses, and single crystals, is the method to fabricate 3D integrated optical circuits with tellurite glass. The films can be fabricated by several methods. In methods involving heat treatment, one must consider the mismatched thermal expansion coefficients between the film and substrate. Cracking, peeling and birefringence present major barriers to device fabrication by such methods. In this study, the waveguide fabrication process was separated into film fabrication and coating process. The film fabrication used glass blowing technique, and the coating process was performed by direct bonding technique.

The glass thin film prepared by glass blowing technique, which introduces air into the molten glass as blowing soap balloon, was investigated first in this study. After measuring the working time of blowing a tellurite glass balloon without crystallization, tellurite glass thin film with 0.45 μm thickness in a large area of 16 cm × 5 cm has been fabricated successfully. The blowing temperatures at 450 ° C, 500 ° C, and 550 ° C were analyzed in this study. The thickness of the glass balloon in the different longitude was measured, and the thinnest place was at the -10° , which is near the equatorial plane when 90° is at the top and -90° is at the bottom. Concave meniscus effect appeared at the top of the balloon because the blowpipe was at the top, the gravity pulled the molten tellurite glass down, and the droplet at the bottom. These three factors cost the -10° becomes the thinnest place.

Tellurite glass thin film was successfully bonded on a silicate glass substrate by the direct bonding method. Tellurite glass film with thickness 1-3 μm was fabricated by the glass blowing technique and the direct bonding process was performed at room temperature at relative humidity of 62% or 15%. The surface adhesive strengths of the glass films bonded at 15% and 62% RH were measured as 250 and 96 mJ/m^2, respectively, by the Obreimoff-Metsik method. The hydroxyl (-OH) functional groups on the interface between the film and silicate glass were analyzed by Fourier transform infrared spectroscopy. The major bonding forces between the tellurite thin film and silicate glass were hydrogen bonds at 62% RH, and the bonds between Te element on the tellurite glass and O element on the silicate glass were critical at 15% RH. These forces, contributed by Si-OH, were important for bond formation at 62%. The large amounts of water and OH groups on the silicate glass, determined by thermogravimetric analysis, indicated a weaker bonding process at 62% RH. This work contributes to the reliable and high-integrity components for the integrated optical circuits, which are increasingly needed for the high-throughput data transfer.

The bonding of tellurite thin film to different substrates was further analyzed. The tellurite thin film was fabricated by glass blowing technique, and the substrates tested here include silicate glass, silicon wafer, tellurite bulk glass, sapphire, and lithium niobate. The adhesive strength of tellurite thin film bonding to substrates was measured, indicating that tellurite thin film formed the weakest bond with silicon wafer after hydrophobic treatment and the strongest bond with tellurite bulk glass. The hydrophilicity of substances was estimated by the contact angle of water droplet on the substances. Results indicated that the hydrophilicity determined the adhesive strength of the tellurite thin film bonding on substances as long as the measurement of contact angle was performed at the same relative humidity. Secondary ion mass spectrometer was further used to determine the elements on and beneath the surface of tellurite thin film and silicate glass substance before and after bonding. Results indicated that the changes of ion distribution in silicate glass were sodium, silicon, and calcium ions, and were sodium, tellurium, and boron ions in the tellurite thin film after bonding, indicating these ions may contribute to the bonding between silicate glass and tellurite thin film.

In this thesis, the tellurite glass thin film was fabricated by glass blowing, and directly bonded to substrate to be a planar tapered waveguide at room temperature. The glass blowing technique has the high potential for thin film fabrication by using glasses with low melting temperature. The direct bonding technique at room temperature is one of the suitable methods for bonding film to substrate without cracking due to the difference of the thermal expansion coefficient between film and substrate. Results of this study provide a feasible method for fabrication 3D optical integrated circuits, which contain mainly silicate materials, with tellurite glass.