Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.738-739

P7-16

# Groove-Buried Optical Waveguides Based on Metal Organic Solution-Derived $Ba_{0.7}Sr_{0.3}TiO_3$ Thin Films

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## 1. Introduction

Recently, much attention has been paid to $(Ba_xSr_{1-x})TiO_3$ (BST) thin films in integrated opto-electronic device applications as they have prominent properties such as large electro-optical coefficient and low optical losses. In this work, a groove-buried type optical waveguide based on metal organic solution-derived $Ba_{0.7}Sr_{0.3}TiO_3$ (BST0.7) thin film was introduced.

## 2. Experiments

A groove-buried optical waveguide was constructed with BST0.7-based core layer and $SiO_2$ cladding layer. The layout cross section of the amorphous BST0.7-based optical waveguide is shown schematically in Fig.1. Figure 2 shows the fabrication process flow. The BST0.7 thin films were fabricated by metal organic decomposition (MOD) technique.

## 3. Results and discussion

Figure 3 shows XRD patterns of about 200 nm thick BST0.7 films postannealed at different temperature. The substrate was fused quartz. A complete pseudo-cubic perovskite phase of BST0.7 appeared at 550℃ for 2h-postannealing. The as-deposited films were amorphous.

Figure 4 depicts the optical transmittance spectra of BST0.7 thin films on fused quartz. All the BST0.7 thin films were highly transparent to light for wavelengths longer than about 370 nm.

In general, high density photonic devices require the use of sharp, e.g. 90$^o$, bends. The BST 90$^o$ bend waveguide structure shown in Fig. 5 was designed on the basis of a double corner mirror structure [1]. The waveguide bend transition angle $\theta$=22.7$^o$ was adopted in this work. The relation between the bent transition distance $l$ and the width $w$ of the waveguide is given by $l = 3.4w$. The bend size was small, $34\mu m \times 34\mu m$, for an optical waveguide with the width of 10 $\mu m$ (SEM picture shown in Fig. 5).

To perform the cutback measurement, the different length waveguides including one bend and three bends (as shown in Fig. 6) were prepared and the transmission of $\lambda = 632.8nm$ light through the waveguide was measured. Assuming the intensity of output light from the waveguide including one bend and three bends are $I_{out1}$ and $I_{out2}$ respectively, their relation can be given as

$$\ln I_{ratio} = 2\ln T - \alpha \bullet \Delta L \quad (1)$$

where $I_{ratio} = \frac{I_{out2}}{I_{out1}}$, $\Delta L = L'_{total} - L_{total}$. $L'_{total}$ and $L_{total}$ are respectively equal to the total length of a waveguide including three bends and one bend, for example $L'_{total} = L'_1 + L'_2 + L'_3 + L'_4$. $\alpha$ is the absorption coefficient of waveguide. $T$ is the optical transmission of the 90$^o$ bend. The optical propagation loss $\alpha_L$ and 90$^o$ bend loss $\alpha_b$ can be calculated from extrapolation of the plot of $\ln I_{ratio}$ versus $\Delta L$. Figure 7 and Figure 8 show the optical losses of amorphous and polycrystalline (postannealed at 550$^o$C for 2h) BST0.7 thin film groove-buried waveguides with the width of 5 $\mu m$ respectively. It was found that the optical propagation losses were about 12.8 and 17 dB/cm respectively for amorphous and polycrystalline thin films. The 90$^o$ bend loss was about 1.2 dB for 5 $\mu m$ wide amorphous BST0.7 waveguides. Comparing sputtering with MOD method, it can be seen that the polycrystalline BST films fabricated by MOD had lower optical propagation losses (as shown in Fig. 9). In addition, the bend loss of the 90$^o$ bent waveguide with a small curvature of micrometers was small which was helpful to make photonic device size scale down and realize the high density integration.

Figure 10 (a) and (b) shows the SEM morphology of cross section and a picture of output light for an amorphous BST0.7 waveguide with 10 $\mu m$ width and 185 nm thickness respectively. It was found that most of light was confined in the BST0.7 core layer on the groove.

## 4. Conclusions

In summary, the amorphous $Ba_{0.7}Sr_{0.3}TiO_3$ (BST0.7) thin film groove-buried waveguides with 90$^o$ bent structure have been successfully fabricated on Si substrates with 1.65 $\mu m$ thick $SiO_2$ thermal oxide layer by using a metal organic decomposition (MOD)-spin-coating procedure. Most of light was confined in the BST0.7 core layer on the groove. The optical propagation losses were about 12.8 and 17dB/cm respectively for amorphous and polycrystalline thin films. The 90$^o$ bend loss was about 1.2 dB for amorphous BST0.7 waveguides with 5 $\mu m$ width at the wavelength of 632.8 nm.

**Acknowledgements**

This study was supported in part by 21st Century COE program "Nanoelectronics for Tera-Bit Information Processing" from the Ministry of Education, Culture, Sports, Science and Technology, Japanese Government.

**References**

[1] R. L. Espinola, R. U. Ahmad, F. Pizzuto, M. J. Steel and R. M. Osgood, Jr. , Optics Express, 8, (2001).

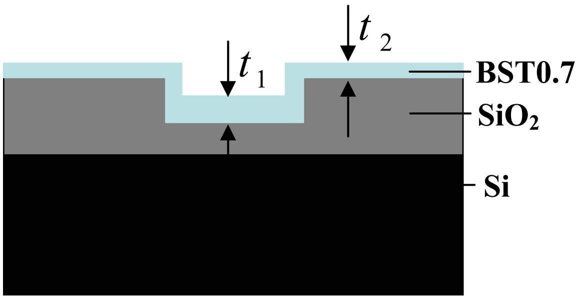


Fig. 1. The layout cross section of the amorphous BST0.7 thin film groove-buried optical waveguide.

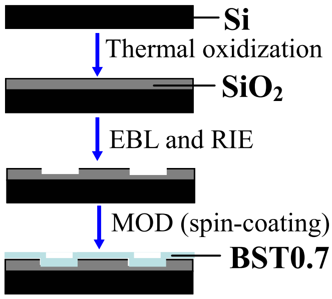


Fig. 2. Fabrication process flow for the amorphous BST0.7 thin film groove-buried optical waveguide.

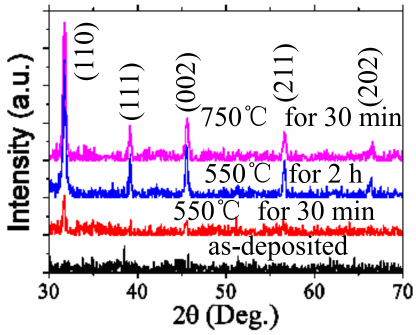


Fig. 3. XRD patterns of about 200 nm thick BST0.7 thin films on fused quartz substrates.

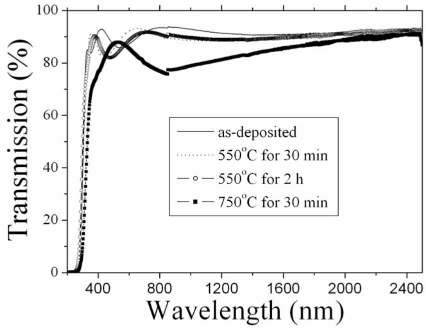


Fig.4. Transmittance spectra of about 200 nm thick BST0.7 thin films on fused quartz substrates.

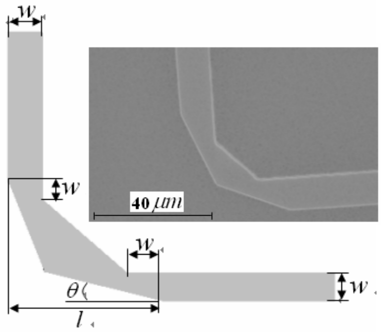


Fig. 5. Schematic picture and SEM morphology of the 90° bend waveguide structure.

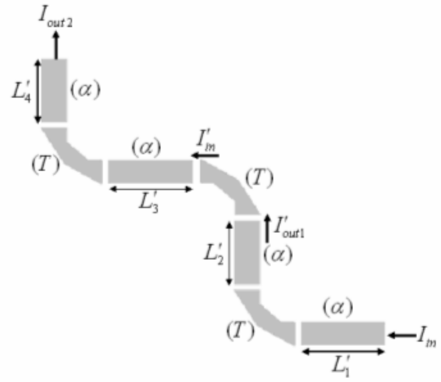


Fig. 6. Schematic picture of the waveguide including three bends.

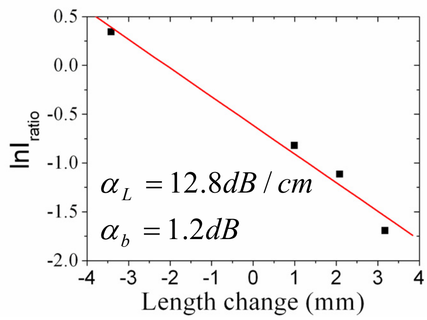


Fig. 7. Plot of $\ln I_{ratio}$ versus the change of waveguide length $\Delta L$ for amorphous BST0.7 film waveguide with about 5 $\mu m$ width and 200 nm thickness.

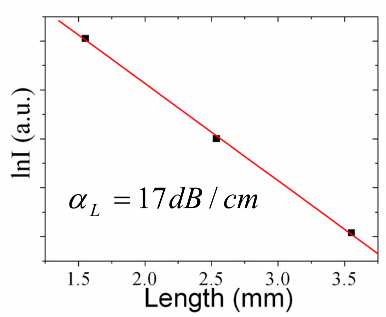


Fig.8. Plot of $\ln I$ versus the waveguide length for poly-crystalline BST0.7 film waveguide with about 5 $\mu m$ width and 350 nm thickness.

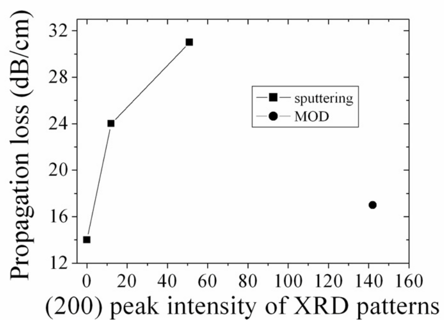


Fig. 9. Plot of optical propagation loss versus (200) peak intensity of XRD patterns.

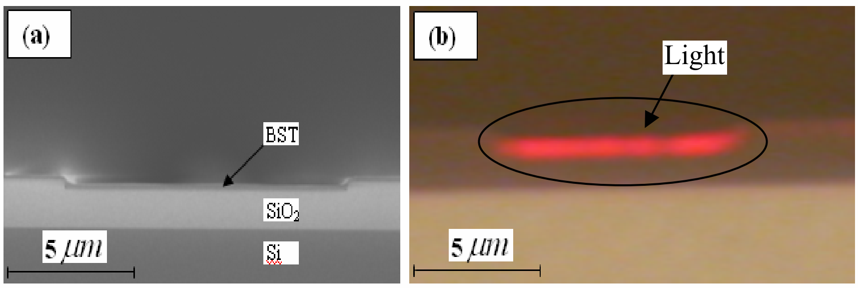


Fig.10. SEM morphology (a) of cross section and a picture (b) of output light for a 10 $\mu m$ wide amorphous BST0.7 groove-buried waveguide respectively.