Analysis of PLC optical sensors integrated with tin oxide thin films

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Abstract - **We proposed optical gas sensors based on PLCs integrated with SnO_2 thin films. SnO_2 thin film was placed on the core layer appeared by removing the upper cladding layer of PLC. The propagation loss is analyzed using 2-D finite-difference time-domain method as a function of refractive index change of SnO_2 thin film. The propagation loss of 0.18 dB was observed when the change of refractive index of SnO_2 thin film was 0.01.**

I. INTRODUCTION

Tin dioxide (SnO_2) belongs to a class of materials that combines high electrical conductivity with optical transparency and thus constitutes an important component for optoelectronic applications [1]. SnO_2 has been widely studied for gas sensor. It has a high reactivity to reducing gases at relatively low operating temperatures and an easy absorption of oxygen at its surface due to the natural non-stoichiometry. Most SnO_2 sensors are operated on the basis of the modification of the electrical properties [2,3]. However, SnO_2 sensors have some drawbacks which, in some cases, limit their use in practice. In particular, their operation principle and high operating temperature lead to high power consumptions and to the difficulty to be exploited in combustible and liquid environment [4]. The use of optical waveguides such as optical fibers and planar lightwave circuits (PLCs) integrated with SnO_2 materials could enable to overcome the aforementioned drawbacks.

In this study, we proposed optical gas sensors based on PLCs integrated with SnO_2 thin films and confirmed their potential application as gas sensors through computational simulation using the two dimensional finite-difference time-domain (2-D FDTD) method.

II. STRUCTURE

The structure of gas sensor using PLC with SnO_2 thin film is shown in Fig 1. The width and the height of PLC were 20 and 40 μm, respectively. The refractive index of cladding layer was 1.4440 at the wavelength of 1.55 μm. The core was 6x6 μm^2 in size. The relative index difference between the core and cladding layers was 0.75%. SnO_2 thin film of 100 nm thickness was placed on the core layer appeared by removing the upper-cladding layer of 100 μm length. In the simulation, the range of the refractive index of SnO_2 thin film was 1.80 ~ 1.82 at the wavelength of 1.55 μm. Table I summarizes refractive index values at the wavelength of 1.55 μm and thickness of the different layers.

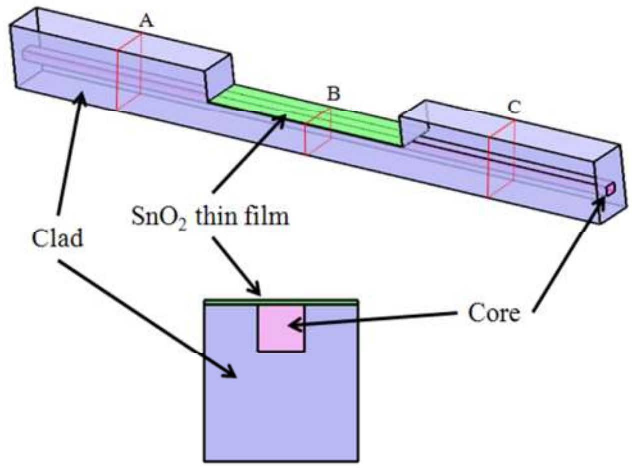

Fig 1. Schematic view of the PLC with SnO_2 thin film.

TABLE I
PARAMETERS OF PLC WITH SnO_2 THIN FILM

	Refractive index @ 1.55 μm	Thickness (μm)
Upper Cladding	1.4440	20
Core	1.4549	6
SnO_2 Thin Film	1.80 ~ 1.82	0.1

III. RESULTS AND DISCUSSION

Beam propagation of the PLC structures with different refractive indices of SnO_2 thin films was analyzed using the 2-D FDTD method. Here, propagation intensity profiles and propagation losses have been obtained.

The propagation intensity profile is shown in Fig. 2 when the refractive index of SnO_2 thin film is 1.8. The propagation mode shifts to the cladding layer in the region of SnO_2 thin film because propagation mode is affected by refractive index of air rather than that of SnO_2 thin film. The calculated length of evanescent wave is about 1.6 μm in the region of SnO_2 thin film. However, the length of evanescent wave is about 10 μm in the region of the core surrounded by cladding layer. Also, scattering loss appears in the boundary between upper cladding layer and SnO_2 thin film.

Figure 3 shows the propagation losses in the PLCs as a function of refractive indices of SnO_2 thin films. The propagation losses are monitored in the region B and C when the optical power was injected into the region A. As the refractive index of SnO_2 thin film increase, the propagation loss increase. It shows the propagation loss of 0.18 dB when the refractive index change of SnO_2 thin film is 0.01.

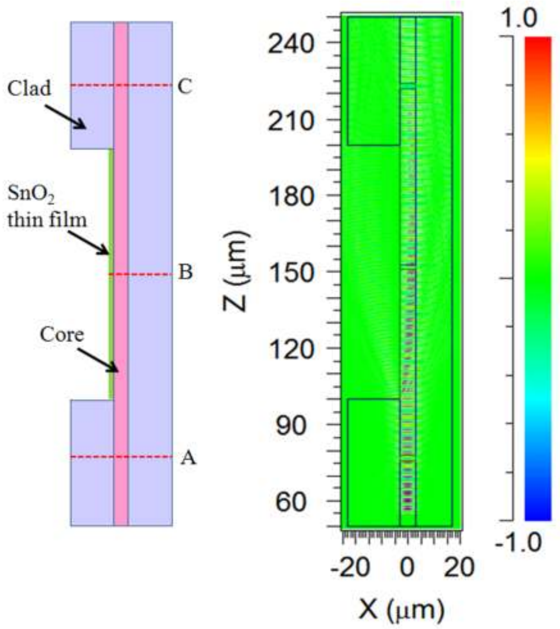

Fig 2. Propagation field intensity profiles in the PLC.

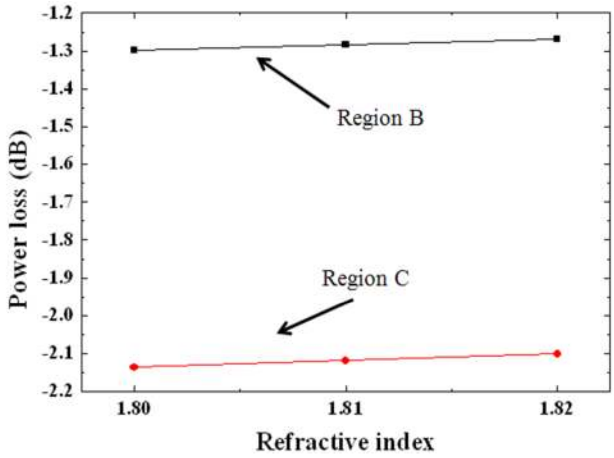

Fig 3. Propagation losses in PLCs as a function of refractive indices of SnO_2 thin films.

IV. CONCLUSION

An optical sensor based on PLC integrated with SnO_2 thin film has been designed. Then, the analysis of beam propagation in the optical sensor structure was conducted as a function of refractive indices of SnO_2 thin films. The propagation loss of 0.18 dB was observed when the refractive index variation of SnO_2 thin film is 0.01. In conclusion, such PLC can be integrated with SnO_2 materials and show the potential as optical gas sensors.

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REFERENCES

[1] M. Batzill and U. Diebold, "The surface and materials science of tin oxide," *Prog. Surf. Sci*., vol. 79, pp. 47-154, 2005.

[2] K. Arshak, E. Moore, G.M. Lyons, J. Harris, and S. Clifford, "A review of gas sensors employed in electronic nose applications," *Sens. Rev.* vol. 24, pp. 181-198, 2004

[3] A. Kolmakov, Y. Zhang, G. Cheng, and M. Moskovits, "Detection of CO and O_2 Using Tin Oxide Nanowire Sensors," *Adv.Mater.* vol. 15, pp. 997-1000, 2003.

[4] A. Buosciolo, M. Consales, M. Pisco, and A. Cusanoet, "Fiber-Optic Near-Field Chemical Sensors Based on Wavelength Scale Tin Dioxide Particle Layers," *J. Lightw. Technol.,* vol. 26, pp. 3468-3475, 2008.