Optik 126 (2015) 3656–3658

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

# Simulation studies for reflected light of polymer waveguide for realisation of temperature

C.S. Mishra, G. Palai *

*Gandhi Institute for Technological Advancement (GITA), Bhubaneswar, India*

ARTICLE INFO

*Article history:*
Received 17 September 2014
Accepted 30 August 2015

*Keywords:*
Polymer waveguide
Temperature
Reflectance
Reflected energy

ABSTRACT

The variation of reflected energy with temperature in polymer waveguide on silicon substrate is presented in this paper. To compute reflected energy from polymer waveguide structure, reflectance from such waveguide is simulated using plane wave expansion method. Simulation result revealed that reflectances as well as reflected energies vary linearly with respect to temperature, which leads to an accurate realisation of temperature in the polymer waveguide.



## 1. Introduction

The burgeon of optical communication and photonic information revolution are becoming major role in the field optical science and technology. To realise the same communication and information, optical waveguide plays vital role. As far as optical waveguide is concerned, it is made of different materials. Of these, polymer materials exhibit various favourable properties for the sake of waveguide technology [1]. There is a great potential for the use of polymers in terms of optical properties, cost effective and processing feasibility [2]. With regard to fabrication of polymer waveguide, various parameters including temperature play an important role for manufacture process [3]. With respect to importance of temperature in polymer wave guide on silicon substrate, this paper realises, the effect of temperature on same waveguide with the help of reflected signal. To realise this, we propose an experimental setup by which one can investigate the temperature in polymer waveguide. The experimental setup is shown in Fig. 1.

To make an understand the temperature effect in the polymer waveguide structure, we have chosen three types of commercial polymer such as $S_1$ (polymethylmethacrylate (PMMA)), $S_2$ (epoxy resin) and $S_3$ (Polystyrene). Here light source having wavelength 1550 nm is incident on polymer waveguide, which is placed on silicon substrate. Then some amount of light gets reflected from the waveguide structure and it is measured at detector. Here heater is used to apply heat to the polymer waveguide. Temperature in the polymer waveguide depends on heat which is a function of reflected energy, so the principle of measurement is the variation of reflected energy from such waveguide with respect to temperature. Since heat is being applied to polymer waveguide structure, temperature influences the structure parameters (refractive indices and thickness) to find out reflectance [4,5]. As far as thickness of such waveguide with respect to different temperature is concerned, it is almost constant for the same heat, however its refractive indices changes with the change of temperature. Here the thickness of silicon substrate is taken of 2 mm. The variation of refractive indices of different polymer samples with temperature is shown in Table 1 [6].

Table 1, represents the variation of refractive indices of $S_1$, $S_2$ and $S_3$ with respect to different temperatures, and varies from 30 °C to 80 °C at the wavelength 1550 nm. Here the thickness 6.76 μm, 8.13 μm and 19.37 μm are considered for samples 1, 2 and 3 respectively.

## 2. Simulation and discussion

Using data from Table 1 and with the help of plane wave expansion method, simulation is made to obtain reflectance of such polymer waveguide with different temperature, which varies from 30 °C to 80 °C [7]. The simulation result for temperature 30 °C of $S_1$, $S_2$ and $S_3$ is shown in Fig. 2(a)–(c) respectively.

Simulation results for other temperatures (35 °C, 40 °C, 45 °C, 50 °C, 55 °C, 60 °C, 65 °C, 70 °C, 75 °C, and 80 °C) are also done but not shown here. Fig. 2(a)–(c) represents the graph between reflectance (Arbi. Unit) along the vertical axis with respect to wavelength

* Corresponding author. Tel.: +91 9439045946.
*E-mail addresses:* gpalai28@gmail.com, g_pallai@yahoo.co.uk (G. Palai).

http://dx.doi.org/10.1016/j.ijleo.2015.08.256
0030-4026/

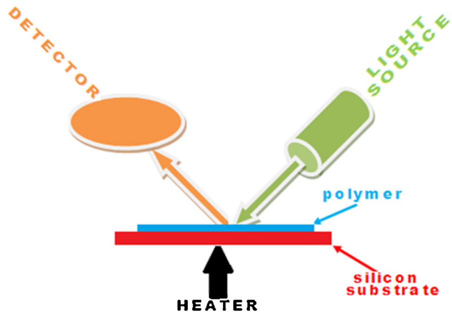


**Fig. 1.** Experimental setup to measure temperature in polymer waveguide structure.

(μm) along horizontal axis for $S_1$, $S_2$ and $S_3$. From these figure it is seen that reflectance varies randomly with respect to wavelength, but we measure the reflectance at wavelength 1550 nm in this paper. Using this concept, from Fig. 2(a)–(c), the reflectance is

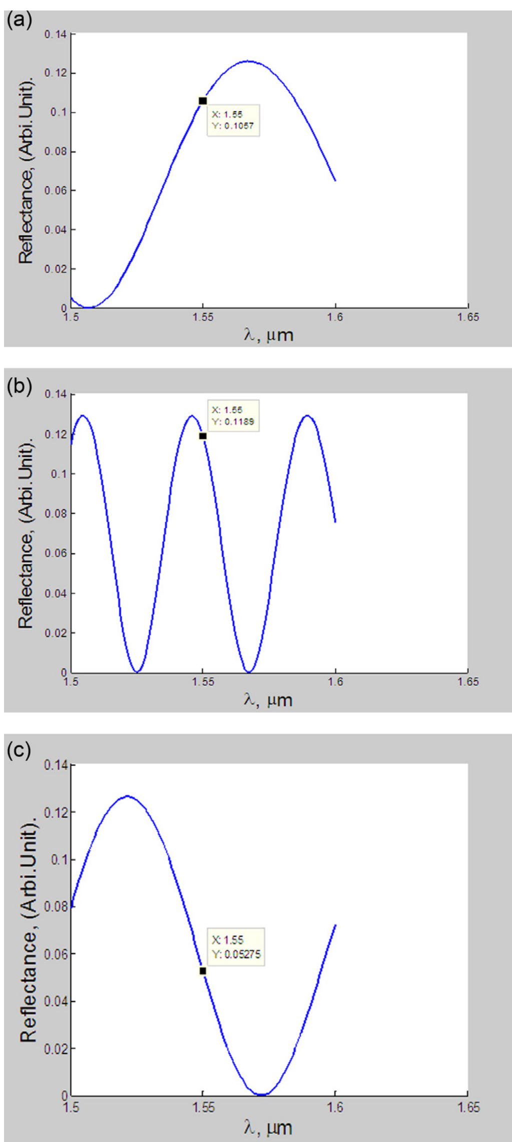


**Fig. 2.** (a) Variation of reflectance with respect to temperature, 30 °C for 1st sample of polymer. (b) Variation of reflectance with respect to temperature, 30 °C for 2nd sample of polymer. (c) Variation of reflectance with respect to temperature, 30° for 3rd sample of polymer.

**Table 1**
Refractive indices of three polymer samples with temperature from 30 °C to 80 °C.

| Temperature | Refractive index | | |
|---|---|---|---|
| | $S_1$ (thickness 6.76 μm) | $S_2$ (thickness 8.13 μm) | $S_3$ (thickness 19.37 μm) |
| 30 | 1.449 | 1.4502 | 1.4565 |
| 35 | 1.4486 | 1.4496 | 1.4558 |
| 40 | 1.4484 | 1.4488 | 1.455 |
| 45 | 1.4472 | 1.4474 | 1.4538 |
| 50 | 1.4466 | 1.4468 | 1.453 |
| 55 | 1.4458 | 1.4452 | 1.4519 |
| 60 | 1.4448 | 1.4444 | 1.451 |
| 65 | 1.4442 | 1.443 | 1.450 |
| 70 | 1.443 | 1.442 | 1.449 |
| 75 | 1.442 | 1.441 | 1.4484 |
| 80 | 1.4416 | 1.4404 | 1.4474 |

found 0.1057, 0.05275 and 0.1189 for sample $S_1$, $S_2$ and $S_3$ at the wavelength 1550 nm and temperature 30 °C respectively. Similarly, reflectance's for other temperatures is also calculated for aforementioned samples. An interestingly, it is found that reflectance for $S_1$ increases linearly from 0.1057 to 0.1170 with respect to temperature 30 °C to 80 °C, where in case of sample 2 and 3, the same reflectance decrease linearly with same temperatures, for examples reflectance's for sample 2 varies from 0.05275 to 0.01579 and reflectance varies from 0.1189 to 0.03784 for sample 3.

Using above values of reflectances for different temperatures of $S_1$, $S_2$ and $S_3$, we compute reflected energy from polymer waveguides using generalised formula, which is given by:

$$E_R = RE_0 \tag{1}$$

where $E_R$ be the reflected energy from polymer waveguide structure, $R$ be the reflectance and $E_0$ be an incident energy having wavelength 1550 nm. Then $E_R$ is computed for each values of $R$ at different temperatures of above mentioned samples ($S_1$, $S_2$, and $S_3$). Finally a graph is plotted between temperatures along $x$-axis with respect to reflected energy along $y$-axis, which is shown in Fig. 3.

From Fig. 3, it is seen that three variations are made for three different samples, i.e. blue colour for $S_1$, red colour for $S_2$ and green colour for $S_3$ at different temperatures. It is also found that reflected energy increases (blue colour) from 84.56 meV to 93.6 meV for $S_1$ with respect to temperature, which varies from 30 °C to 80 °C. Similarly reflected energy decreases $S_2$ (red colour) from 42.2 meV to 12.632 meV for $S_2$ and 95.2 meV to 30.20 meV (green colour) for $S_3$ with respect to same temperatures. Apart from this it is also seen that the variations for all three samples are excellently fitted with linearship ($R^2$ = 0.9929 for $S_1$, $R^2$ = 0.9922 for $S_2$ and $R^2$ = 0.9986

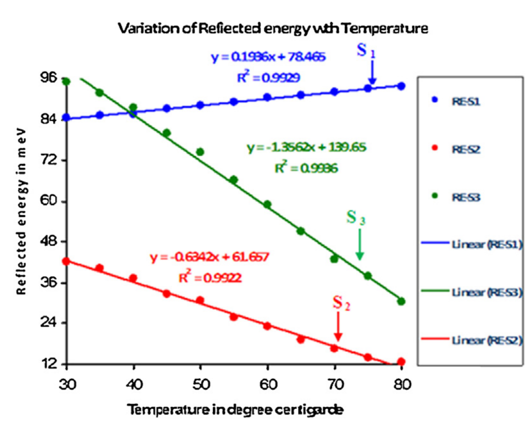


**Fig. 3.** Variation of reflected energy with respect to temperature for $S_1$, $S_2$ and $S_3$. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.)