

Modelling overall transmitted efficiency at 1550 nm for polymer grating Silicon-on-insulator structure with defect

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Abstract The overall transmitted efficiency at 1550 nm for Nylon-Teflon/Teflon-Nylon (N-T/T-N) grating Silicon-on-insulator (SOI) structure with defect in even and odd position was investigated in this paper. Different types of losses, such as absorption, reflection and diffraction, were considered to find out the overall transmitted efficiency. The absorption loss of both Nylon-Teflon (N-T) and Teflon-Nylon (T-N) structure is zero at the wavelength of 1550 nm. Reflectance of these structures was analyzed by using plane wave expansion (PWE) method. Simulation result showed that reflectance as well as transmittance was varied linearly with respect to defect at odd and even positions. Simulation is also done for the diffraction efficiency at 1550 nm with respect to detuning from Bragg's angle, which was ranged from -0.4 rad to $+0.4$ rad. Finally, it was found that overall transmitted efficiency increased as even defect position varied from 2nd to 10th for both N-T/T-N grating SOI structure. Similarly, the overall transmitted efficiency decreased as odd defect position changed from 3rd to 11th for both N-T/T-N grating SOI structure.

Keywords overall transmitted efficiency, Nylon-Teflon/Teflon-Nylon (N-T/T-N) grating, plane wave expansion (PWE), Silicon-on-insulator (SOI)

1 Introduction

Nowadays, Silicon-on-insulator (SOI) arouses a lot of interest, since this offers wide compatibility. SOI is also a critical platform for integrated optoelectronics circuits, since it has the potential for monolithic integration for photonic and electronic function on a single substrate [1]. Integrating photonic functions on a silicon platform is a low cost solution, nowadays. Recently, SOI has played a

vital role for the sake of photonic applications [2,3]. So SOI needs high efficiency for these applications. To obtain high efficiency grating SOI structure, one has to choose suitable input parameters of the grating structure, which is placed on SOI. As far as we know, many papers reported only dealing with absorption loss, but few papers presented dealing with reflection loss as well as absorption loss [4–7]. Recently, SOI grating structure has been considered with the losses of absorption, reflection and diffraction [8,9]. In this case, authors consider periodic silicon grating structure. But here, we have considered polymer grating having defects at odd and even positions, where all three types of losses (absorption, reflection and diffraction) are considered. In this paper, we deal with Nylon-Teflon (N-T) and Teflon-Nylon (T-N) grating SOI structure, having defect at different even and odd positions. The schematic diagram of N-T grating having defect at the 2nd position and T-N grating having defect at the 3rd position is shown in Figs. 1(a) and 1(b) respectively, and air is taken as defect instead of Nylon or Teflon layer.

It is also seen from Fig. 1 that the detuning from Bragg's angle (θ) lies between -0.4 rad to $+0.4$ rad as light with the wavelength of 1550 nm is incident on grating SOI structure.

This paper is organized as follows: mathematical approach is mentioned in Section 2; the grating structure analysis is discussed in Section 3; in Section 4, result and discussion are presented; finally, conclusions are drawn in Section 5.

2 Mathematical approach

According to Ref. [10], reflectance is computed with respect to wavelengths. The transmitted efficiency for polymer grating structure is written as [11]

$$\eta_T = (1-R)^2 e^{-6\beta(t_1+t_2)}, \quad (1)$$

where R is the reflectance, β is the absorption coefficient of

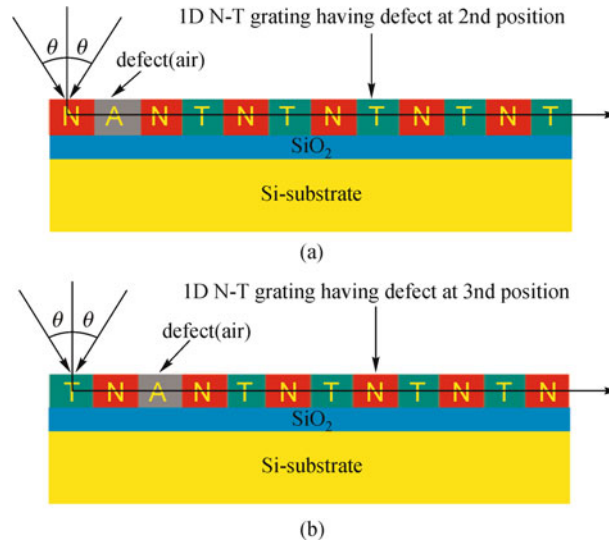


Fig. 1 (a) N-T grating SOI structure having defect at the 2nd position; (b) T-N grating SOI structure having defect at the 3rd position

materials. t_1 and t_2 are the thickness of odd and even layers, respectively.

And the diffraction efficiency of the polymer grating structure can be expressed as [12]

$$\eta_d(\theta) = \left(\frac{\pi n d}{\lambda \cos \theta} \right)^2, \quad (2)$$

where d is grating length, n is the refractive index modulation, θ is the angle of deviation from Bragg's angle, λ is the wavelength of signal.

Finally, the overall transmitted efficiency of waveguide (η) is expressed as

$$\eta = \eta_T \times \eta_d, \quad (3)$$

where η_T is transmitted efficiency and η_d is diffraction efficiency.

3 Grating structure analysis

In this paper, we have considered two polymer grating structures, such as Nylon-Teflon (N-T) and Teflon-Nylon (T-N), which is respectively depicted in Fig. 2(a).

Figure 2(a) represents N-T grating structure having '6' periods.

In Fig. 2(a), t_1 and t_2 are the thickness of odd and even layer respectively. This structure consists of regular periodic of Nylon (N) and Teflon (T) materials. Since we deal with defect grating structure, first defect is considered at the 2nd position; i.e., Teflon material is replaced by air. And this grating structure is shown in Fig. 2(b).

Similarly defect is made at the 4th position shown in Fig. 2(c), the thickness of Teflon materials is remain same.

Like this, position (even) of defect gradually moves

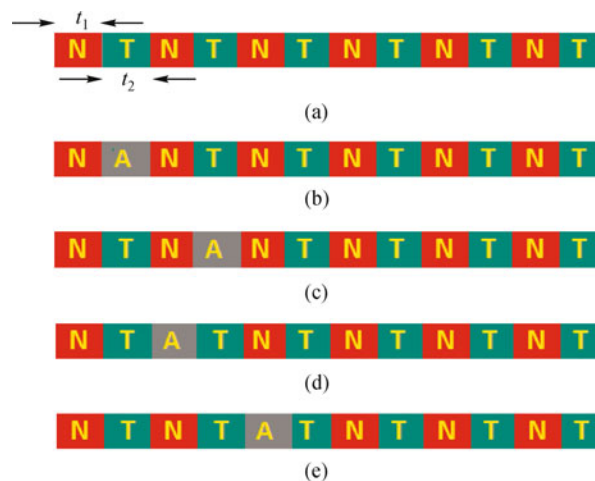


Fig. 2 (a) Periodic N-T grating structure; (b) N-T grating structure having defect at the 2nd position; (c) N-T grating structure having defect at the 4th position; (d) N-T grating structure having defect at the 3rd position; (e) N-T grating structure having defect at the 5th position

toward right up to the 10th, which is separately at the 2nd, 4th, 6th, 8th, and 10th. Similarly, defect is made at odd position of the aforementioned grating structure. Fig. 2(d) represents N-T grating structure having defect at the 3rd position.

In this case air replaces Nylon (N) material, which is treated as defect and thickness of defect is same of Nylon. Again considering defect at the 5th position instead of the 3rd one, the grating structure is shown in Fig. 2(e).

Similarly the position (odd) of defect moves toward right up to the 11th, which is respectively at the 3rd, 5th, 7th, 9th, and 11th.

Again, the same procedure is applied for even and odd defect position in Teflon-Nylon (T-N) grating structure to obtain even and odd defect grating SOI structure.

Considering above grating structures, we have made simulation to obtain the minimum reflectance at 1550 nm using plane wave expansion (PWE) method. Then, we have also carried out the simulation to find out the diffraction efficiency at same wavelength with respect to detuning from Bragg's angle (θ), which varies from -0.4 rad to $+0.4$ rad. And finally, overall transmitted efficiency is calculated correspondingly at each defect in N-T/T-N grating SOI structure.

4 Result and discussion

To obtain high overall transmitted efficiency, we have chosen proper input parameter of the defect N-T/T-N grating SOI structure, which is described in Table 1.

Taking data from Table 1, simulation is carried out using PWE method to obtain the minimum reflectance at wavelength 1550 nm. The simulation result for reflectance

Table 1 Grating structure parameter

material	refractive index	thickness
Teflon	1.53	430 nm
Nylon	1.35	170 nm
air	1.0	

of N-T grating SOI structure having defect at the 2nd and 4th positions is shown in Figs. 3(a) and 3(b), respectively.

Other simulations are also done but not shown here. From Figs. 3(a) and 3(b). It is seen that wavelength in μm is taken along horizontal axis, where reflectance in r.u. is taken along vertical axis. Since we eager to calculate the reflectance at $1.55 \mu\text{m}$, the inset in this diagram indicates the magnified portion of the reflectance at wavelength $1.55 \mu\text{m}$. The circle (○) in the inset indicates that the wavelength $1.55 \mu\text{m}$ along horizontal axis. It is found from the above inset that, reflectance is 0.1350. And similarly from Fig. 3(b), it is found that reflectance is 0.1134 at wavelength $1.55 \mu\text{m}$.

Similarly, the reflectance of N-T grating SOI structure

having defect at other even positions (6th, 8th, 10th) is also found. Again using Eq. (1), transmitted efficiency is also determined, then a graph is plotted between defect at even positions along x -axis and reflectance/transmittance is taken along y -axis, which is shown in Fig. 4.

From Fig. 4, it is seen that reflectance decreases and transmittance increases from the 2nd to 10th position (left to right) of the N-T grating structure.

Again using Eq. (2), simulation is made to find out diffraction efficiency with respect to detuning angle from Bragg's angle (θ) of N-T grating SOI structure having defects at different even positions. The simulation results for diffraction efficiency of N-T grating SOI structure having defect at the 2nd and 4th position is shown in Figs. 5(a) and 5(b), respectively.

From Figs. 5 (a) and 5(b), it is found that detuning angle of deviation from Bragg's angle in radiation is taken along x -axis, where diffraction efficiency is taken along y -axis. It is also seen from Fig. 5 (a) that, diffraction efficiency is more than 0.85 (85%) with respect to detuning angle which varies from -0.4 rad to $+0.4$ rad. And it is seen from Fig. 5(b) that, diffraction efficiency is more than 0.87 (87%) with respect to detuning angle, which varies from -0.4 rad to $+0.4$ rad. Similarly, diffraction efficiency for other defect positions are also obtained, but not shown here.

Finally, using Eq. (3), overall transmitted efficiency of N-T grating SOI structure having defect at even positions is calculated. And then a graph is plotted between overall transmitted efficiency along y -axis with respect to defect positions (even) along x -axis, which is shown in Fig. 6.

From Fig. 6, an interesting linear variation is observed, for an example; overall transmitted efficiency increases from 0.736 (73.6%) to 0.962 (96.2%) as even defect position moves from the 2nd to the 10th. Apart from this, it is also seen that an excellent trend line is fitted with this variation.

Using the same procedures, we have made simulation to obtain reflectance/transmittance and diffraction efficiency and then the overall transmitted efficiency for N-T grating SOI structure having defect at different odd positions is calculated. Figure 7 shows the overall transmitted efficiency along y -axis with respect to defect positions (odd) along x -axis for N-T grating structure.

From Fig. 7, it is evident that overall transmitted efficiency varies from 0.963 (96.3%) to 0.581(58.1%) as defect positions (odd) changes from the 3rd to the 11th. Apart from this it is also found that trend line is an excellently fitted with this variation.

Again, using the same procedure and technique, overall transmitted efficiency for T-N grating SOI structures are analyzed. Interestingly, it is found that the overall transmitted efficiency varies linearly with respect to even as well as odd defect position of T-N grating structure. Figures 8 and 9 show the variation of overall transmitted efficiency with even and odd defect position in T-N grating SOI structure, respectively.

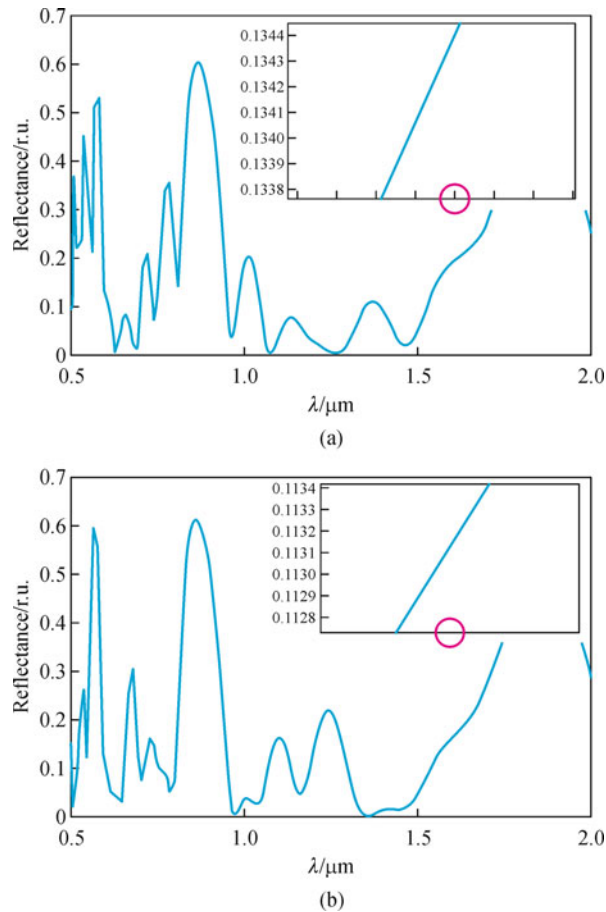


Fig. 3 Reflectance graph of N-T grating SOI structure having defect (a) at the 2nd position and (b) at the 4th position

Figure 8 shows a linear variation of overall transmitted efficiency, for an example, it increases from 0.581 (58.1%) to 0.963 (96.3%) as even defect position increases from the 2nd to the 10th. It is also found that a linear trend line is fitted an excellently with this variation.

Similarly, from Fig. 9, it is observed that overall transmitted efficiency varies linearly with respect to odd defect position, for an example, overall transmitted efficiency decreases from 0.962 (96.2%) to 0.736 (73.6%) as odd defect position increases from the 3rd to the 11th. Again, an excellent linear trend line is fitted with

the same variation.

5 Conclusions

Different types of losses (absorption, reflection and diffraction) are considered to obtain the overall transmitted efficiency of defect Nylon-Teflon and Teflon-Nylon grating SOI structure. Reflectance is simulated using PWE method. Diffraction efficiency of these structures is obtained with respect to detuning angle, which varies from -0.4 rad to $+0.4$ rad. It is seen that overall transmitted

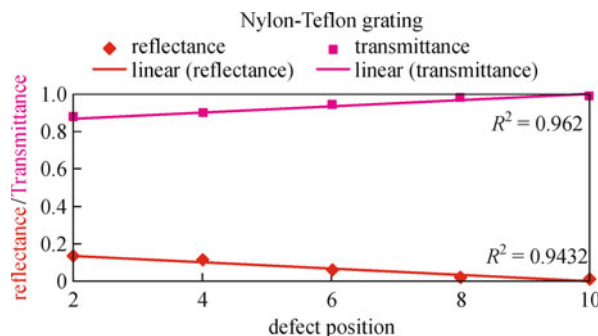


Fig. 4 Reflectance/Transmittance with respect to even defect position, N-T grating

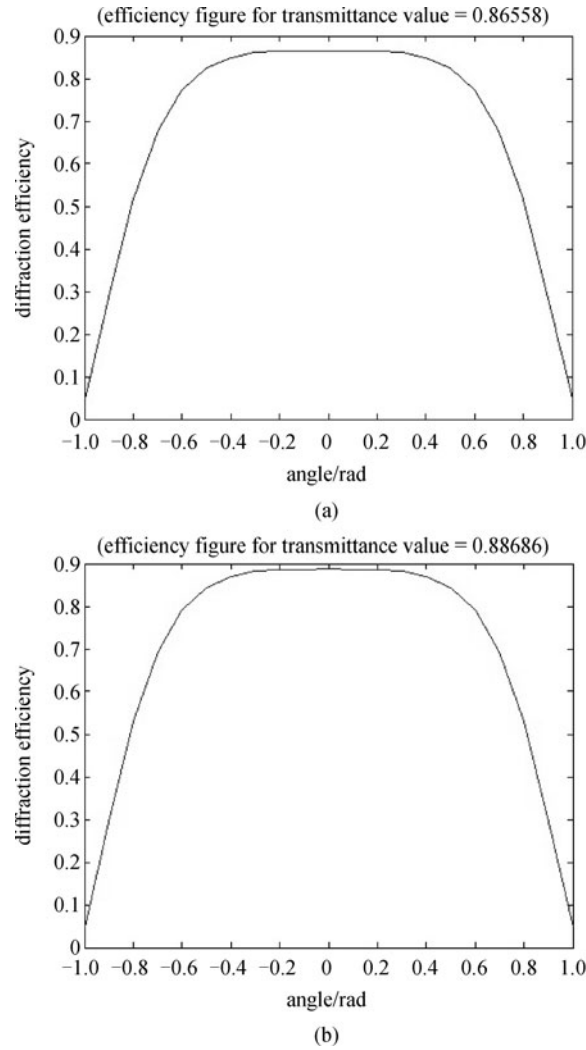


Fig. 5 Variation of different efficiency with respect detuning angle of N-T grating structure having defect (a) at the 2nd position and (b) at the 4th position

efficiency varies linearly with respect to odd as well as even defect position for both Nylon-Teflon and Teflon-Nylon grating SOI structure. It is also found that overall transmitted efficiency gradually increases with respect to even defect position of Nylon-Teflon grating as well

as Teflon-Nylon grating SOI structure, whereas, it gradually decreases with respect to odd defect position of Nylon-Teflon grating as well as Teflon-Nylon grating SOI structure.

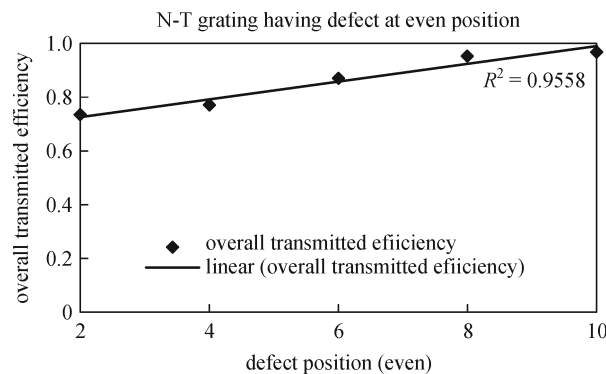


Fig. 6 Overall transmitted efficiency with respect to defect position (even) in N-T grating SOI structure

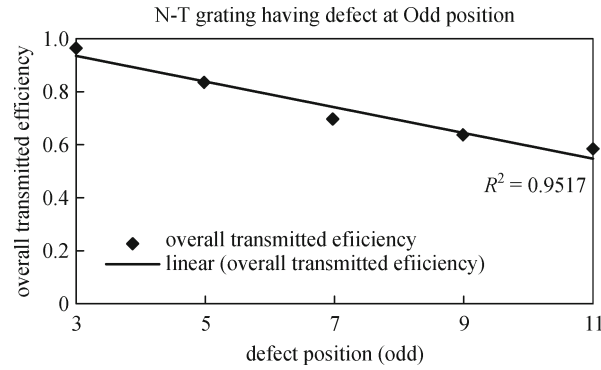


Fig. 7 Overall transmitted efficiency with respect to defect position (odd) in N-T grating SOI structure

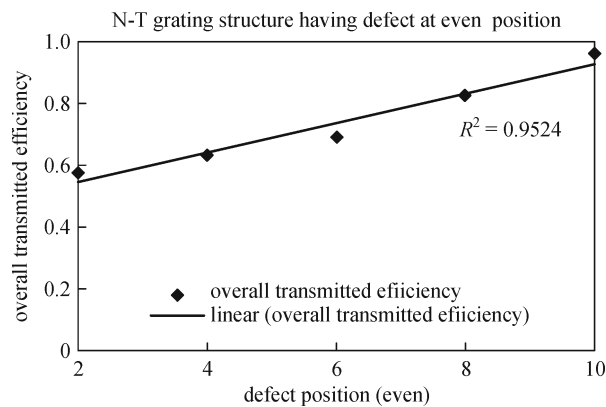


Fig. 8 Overall transmitted efficiency of T-N grating SOI structure having defect at even position

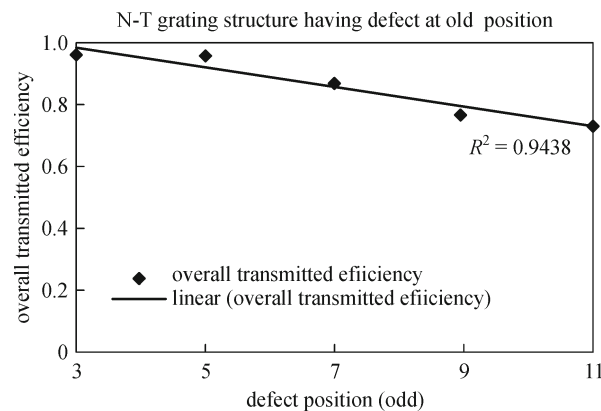


Fig. 9 Overall transmitted efficiency of T-N grating SOI structure having defect at odd positions

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