STUDY ON LOSS CHARACTERISTIC OF POLYMER MATERIAL FOR OPTICAL WAVEGUIDE APPLICATION

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ABSTRACT

Communication technologies today are increasingly reliant on the manipulation of optical signals where previously electronic circuit manipulated those signals. With photonic technology, devices are no longer limited only to the silicon wafer because it also not requires broader functionality than can be offered on this traditional platform. Optical waveguides using polymer materials are attractive for telecommunication applications due to their low costs and simple processing steps compared to silica-based materials. Many advantages in term of optical properties have been proved by the polymer waveguides. Polymer waveguides are potentially useful for short distance optical interconnections. The most important characteristic of a waveguide is the attenuation or loss experienced by light wave as it travels through the waveguide. This dissertation focused on loss measurement of BCB polymer waveguides. Sample of waveguides with variation thickness have been fabricated by deposition of the polymer solution onto glass substrate. The measurement is done by using two types of wavelength that is 630nm and 1550nm. After analyzed all the coupling method, prism coupler method is considered as one of the best ways to couple large amount of light in planar optical waveguides. Furthermore it can be used to determine the loss of polymer waveguide and its characteristics. Investigation of the polymer waveguides with respect to temperature and water also done to see its stability.

ABSTRAK

Komunikasi pada hari ini semakin beralih kepada isyarat optik yang mana sebelum ini di manipulasi oleh litar elektronik. Dengan teknologi fotonik, peralatan tidak lagi bergantung kepada lapisan silika kerana ia memerlukan fungsi yang lebih luas daripada yang telah diberikan oleh platform tradisional. Pemandu gelombang optik menggunakan polimer mempunyai daya tarikan untuk aplikasi telekomunikasi kerana kos yang rendah dan langkah pemprosesan yang ringkas berbanding dengan bahan berasaskan silika. Banyak kelebihan di dalam terma ciri-ciri optik yang telah dibuktikan oleh pandu gelombang polimer. Pandu gelombang polimer berpotensi berguna untuk sambungan optik jarak dekat. Ciri-ciri yang paling penting di dalam pandu gelombang adalah pelemahan atau kehilangan cahaya yang merentasi pandu gelombang polimer. Sampel pandu gelombang dengan ketebalan yang berbeza telah di fabrikasi dengan menggunakan polimer ke atas substrat kaca. Pengiraan dilakukan dengan menggunakan dua jenis panjang gelombang iaitu 630nm dan 1550nm. Setelah menganalisis kaedah-kaedah gandingan yang ada, kaedah pengganding prisma adalah cara terbaik untuk menggandingkan cahaya yang banyak di dalam pemandu gelombang polimer. Tambahan pula ia boleh digunakan untuk menentukan kehilangan pemandu gelombang dan sifat-sifatnya. Pemandu gelombang polimer juga di kaji terhadap kesan suhu dan air untuk melihat stabilitinya.

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LIST OF SYMBOLS

θ_{max}	-	Maximum Light Acceptance Angle
ρ_v	-	Current Density.
$\overline{D}$	-	Electric Field Density,
ϕ	-	Propagation Angle
$\overline{E}$	-	Electric Field Intensity
$\overline{B}$	-	Magnetic Field Density
$\overline{H}$	-	Magnetic Field Intensity
I_{max}	-	Maximum Transmitted Intensity
I_{min}	-	Minimum Transmitted Intensity
m.	-	Mode Number
n_1	-	Refractive Index of Cladding Region
n_2, n_f	-	Refractive Index of The Thin Film
n_3, n_s	-	Refractive Index of Substrate Layer
n_a	-	Refractive Index of Air
n_p	-	Refractive Index of The Prism
r	-	Reflection Coefficient.
T	-	Transmission Reflection Coefficients
α	-	Attenuation Coefficient
β	-	Propagation Constant
ε	-	Permittivity of a Medium
η	-	Coupling Efficiency
θ_c	-	Critical Angle of Total Internal Reflection
θ_i	-	Incident Angle,
θ_m	-	Incident on The Prism Face At An Angle

κ	-	Coupling Coefficient.
λ	-	Wavelength
λ_c	-	Cutoff (free space) Wavelength
μ	-	Permeability of a Medium
σ^2	-	Variances
Φ	-	Phase Shift

LIST OF ABBREVIATIONS

AWG	-	Arrayed Waveguide Grating
AWG	-	Arrayed-Waveguide Grating
BCB	-	B-Staged Bisbenzocyclotene
NA	-	Numerical Aperture.
OADM	-	Optical Add/Drop Filter/Multiplexer
OEO	-	Optical-Electrical-Optical
OIC's	-	Optical Integrated Circuits
PIC's	-	Photonic Integrated Circuits
TDM	-	Time Division Multiplexing
TE	-	Transverse Electric
TEM	-	Transverse Electromagnetic Mode
TLS	-	Tunable Laser Source
TM	-	Transverse Magnetic
VCSEL's	-	Vertical-Cavity Surface-Emitting-Laser
VLSI	-	Very Large-Scale Integrated
VOA	-	Variable Optical Attenuator

CHAPTER 1

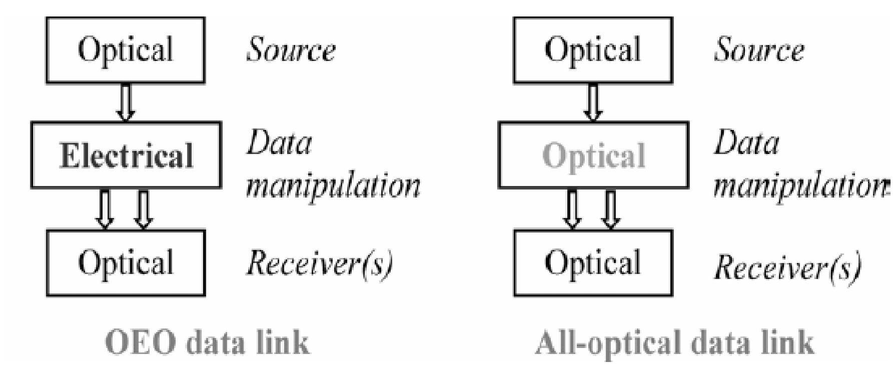
INTRODUCTION

1.1 Introduction

There is a great interest in creating optical integrated circuits (OIC's) or photonic integrated circuits (PIC's) that are capable of switching optical rather than electrical signal. The fundamental difference between existing optical networks and future all-optical networks is illustrated in Figure 1. 1. Current data networks typically handle several signal formats by transmitting optical signals over long distances via single-mode fibers and performing data manipulation, such as switching and filtering, on electrical signals. Therefore, current networks require an optical-electrical-optical (OEO) signal conversion step, one that is costly in terms of network speed, bandwidth, power consumption, hardware complexity, and signal integrity (noise). All-optical switching refers to the direct manipulation and routing of optical signals without the need for an intermediate conversion to electrical signals before switching takes place.

It is expected that future networks will avoid the OEO signal conversion step by performing all data manipulation directly on optical signals, thereby greatly increasing network performance. The field that will enable all-optical data manipulation is referred to as integrated optics. It is envisioned that integrated optical circuits will eventually reach a complexity similar to that of very large-scale integrated (VLSI) electronic circuits where this electronic circuits will be replaced by photonic circuits. With photonic technology, devices are no longer limited only to the silicon wafer and often require broader functionality than can be offered on this traditional platform. Recently, polymeric optical waveguide are becoming increasingly important because of the functionality and complexity that can be fabricated reliably at low cost with high manufacturing output.

This project discusses the fabrication and loss characterization of polymer based optical waveguide. Slab waveguides were fabricated by deposition of polymer onto substrate to form a film layer and spinning the substrate on the spinner to spread the layer evenly. Different thicknesses of slab waveguide are realized by using different spin speed. Photo BCB is used as a polymer material and the loss was measured by using prism coupler technique. The behaviours of these polymer waveguides are then investigated with respect to temperature and water to see its stability. The next section in this chapter presents the objectives, scopes and research methodology of this thesis. Description of thesis outline is presented at the end of this section.



(a) (b)

Figure 1.1: (a) optical-electric-optical (OEO) and (b) all optical datalink.

1.2 Objectives

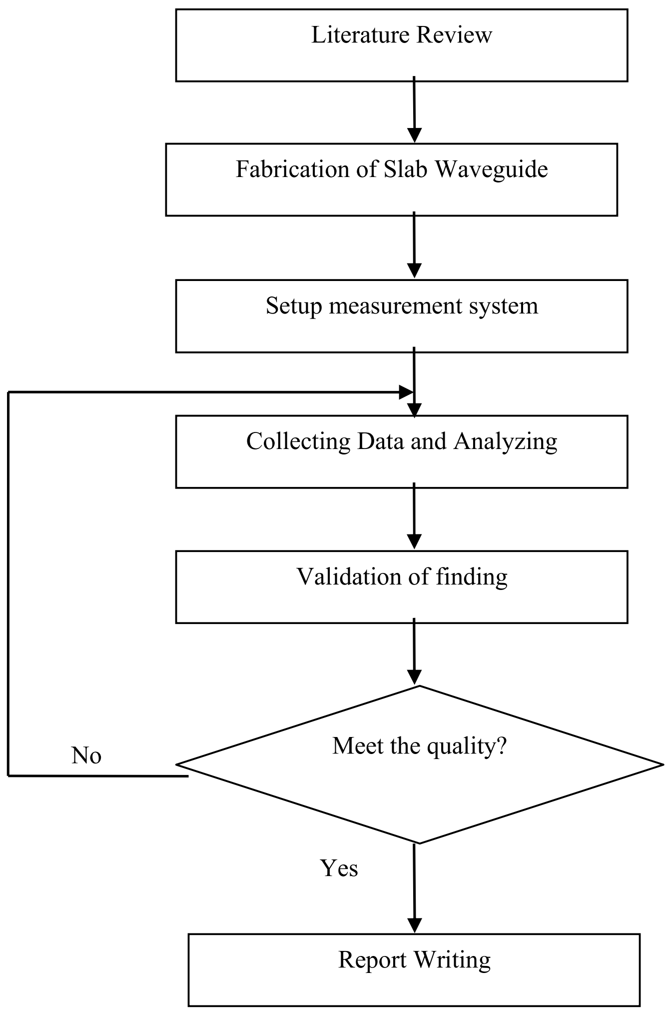
i. To fabricate polymer slab waveguide and acquire the experience on the fabrication process
ii. To setup measurement system in order to determine the attenuation of polymer based optical waveguide
iii. To identify possible polymer material for the purpose of developing a polymer based optical waveguide

1.3 Scope of research

i. To understand fundamentals of related areas including optical waveguide and optical measurement technique.
ii. To study properties of cyclotene 4024-40 photo polymer from the given specifications.
iii. To understand and practice in house fabrication process of slab waveguide.
iv. To setup a measurement system.
v. To measure loss of the fabricated slab waveguides using setup system.
vi. To test the waveguides stability towards thermal and water
vii. To analyze measured results.

1.4 Methodology

Two main stages are employed in order to fulfill the objectives of this project. The first stage is to acquire the basic knowledge about optical waveguides. Journals and papers will be referred to enhance the understanding and to get the overview of the projects. The second stage is to concentrate in exploring the important characteristic in designing optical devices. In order to design an optical device, there are many criteria that need to be considered such as the material that we want to use, the application of the optical devices and how much cost is needed to design it. This is followed by understanding the actual fabrication process of a polymer based optical waveguide. There are many important properties to determine the quality of a waveguide such as its attenuation, refractive index, birefringence, thermo optics coefficient and thickness. This project is focused on the attenuation of polymer based slab waveguides. Therefore simple measurement system based on the prism coupling technique is developed. All results are collected and analyzed, and the performances of these waveguides are then evaluated. Lastly, a report will be written which composed of all findings, results and conclusion.



1.5 Thesis Outline

This thesis is organized into 6 chapters. Chapter 1 discusses the general explanation of polymer based optical waveguide, coupling method and the application of this polymer waveguides in the industry. The objectives that need to be achieved, the scope of research and the methodology used in this project are also described in this chapter. In chapter 2, the theory of planar slab waveguides is reviewed. These includes the derivation of mode in slab waveguides, the losses that encountered in the optical waveguides and some of the measurement methods that are used to measure loss of optical waveguides. At the end of this chapter, it will discuss the polymeric optical waveguides, its material characteristic and the applications. The fabrication process of slab waveguide is explained in chapter 3. Details of every stage are clarified here. Prism coupler which is the method used in this project is described in chapter 4. In chapter 5 the results from the measured data are presented and analyzed. Finally the conclusions of the research will be drawn and some suggestions for further work will be recommended in Chapter 6.

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