Fabrication and Characterization of Directional Couplers as Power Dividers

Alan Andriawan¹, Lucky Putri Rahayu², and Yono Hadi Pramono¹

Abstract—This paper is about directional coupler fabrication results in a slab structure with a substrate in the form of acrylic glass, a film of nano SnO₂, and cladding in the form of methyl methacrylate (MMA). The length of the interaction area (Lc) directional coupler of the fabrication result is 5 mm with a gap width (g) of 0.353 mm. SnO₂ film is grown by deposition on an acrylic substrate. To facilitate the characterization process, the directional coupler is given an optical fiber as input. SnO₂ film which has been deposited on an acrylic substrate is coated with methyl methacrylate (MMA). Coating of methyl methacrylate (MMA) in SnO₂ film is done by the doctor blade method. Directional coupler fabrication results are used as optical power dividers. The fabricated directional coupler is narrated using a He-Ne laser with a wavelength of 632.8 nm. The characterization mechanism is carried out by taking a photo of the cross section of the directional coupler when given a laser beam input. The cross section photos are processed using ImageJ software to determine the directional coupler intensity distribution on each port. Based on the results of the characterization, the directional coupler with the 5 mm Lc output percentage is 26%, 24%, and 49%.

Keywords—Doctor Blade, Methyl Methacrylate (MMA), SnO₂ Nano.

I. INTRODUCTION

In simple optical instruments and systems, light is transmitted between different locations in the form of light that is collimated, illuminated, focused, and scanned by mirrors, lenses, and prisms. The beam flexes and spreads as they propagate even though they can be refocused using lenses and mirrors. However, the largest optical component consisting of such components is often large and difficult to use, and objects that are on the path of light can block or scatter the beam [1].

In some cases, it is an advantage to transmit optical light through the dielectric channel rather than passing free space. The technology to achieve this is known as optical waveguides. The technology was originally developed to serve long-distance light transmission without requiring the use of combined lenses. This technology now has many applications. Some small examples include bringing light through long distances for optical wave communication, biomedical imaging where light must reach a tortuous location, and connecting between miniature optics and optoelectronic components with systems [1].

¹Alan Andriawan and Yono Hadi Pramono are with Department of Physics, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia. E-mail: yonohadipramono@gmail.com.
²Lucky Putri Rahayu is with Department of Electrical Automation Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia.
optic switches for directional coupler polymers [6], LiNbO3
directional couplers based on photonic cables [7], TE / TM
splitter polarization on LiNbO3 photonic cables [8] and
many more advanced experiments related to the
development and design of directional couplers.

Semiconductor metal oxides such as tin oxide (SnO), zinc
oxide (ZnO) and indium oxide (InO) have been widely
studied because they show useful optical and electronic
properties [9]. SnO2 is a non-stoichiometric semiconductor
with Eg (energy gap) > 3.6 eV at room temperature with a
tetragonal structure. The SnO2 layer has unique
characteristics such as high transmittance at visible
wavelengths, low resistivity, high stability compared to
other transparent conductive oxides (TCOs). The SnO2 layer
is widely used in optoelectronics applications such as
window film coatings, photocatalysts, organic LEDs, gas
sensors and solar cells. There are several methods for
preparing SnO2 thin films, including molding techniques,
chemical vapor deposition, reactive evaporation, dc and rf
sputtering, laser pulse ablation, thermal evaporation, organic
metal deposition, sol-gel deposition and spray pyrolysis [9].

Research and development of directional couplers in the
above exposure certainly requires laboratory equipment that
supports the fabrication and characterization of an adequate
directional coupler component and requires no small amount
of funds.

On the other hand, fabrication and characterization of
directional couplers with slab structure based on polystyrene
and polymethyl methacrylate (PMMA) polymers have been
carried out using spin coating method. The resulting
directional coupler is multimode with a coupling length of
0.18 cm, the measurement results and 20.84 μm simulation
results [10]. The study was continued with the fabrication of
wave guides TiO2 nano y-branch with lithography method
as a power divider and obtained the value of power loss for
the y-branch channel of 43.4% [11]. And the study was
continued result of absorbance and transmittance using UV-
Vis known that the highest absorption (262 nm), average
transmittance (91 %) and the thickness of the film obtained
131.6 μm [12].

Based on the results of the research described, it is
possible to experiment with directional coupler structure of
slab structure as a power divider using nano SnO2 film.

II. METHOD

Fabrication and directional coupler characterization as a
power divider begins with the preparation of an acrylic glass
substrate. The preparation stage includes making a substrate
that is acrylic cutting with a thickness of 2 mm in size
according to the design. Acrylic cutting is done using a laser
cutter. It aims to make the acrylic edge look neater.

The pattern of each waveguide to be fabricated is formed
through an engraving process. This process is similar to a
laser cutter, only the power used in the engraving process is
not as large as at the time of cutting, so the substrate that is
gathered is not cut off. The acrylic design that will be used
is presented in Figure 1.

The directional coupler waveguide pattern is formed
through laser engraving and laser cutting. For the directional
coupler, two layers of acrylic are required with the details of
the bottom for engraved acrylics and the top for cut acrylics.

The directional coupler design above is used as the bottom
waveguide channel. As for the upper waveguide channel, the
same acrylic design is used but not through the engraving
process. The upper waveguide channel is made by cutting
acrylic that has been previously designed with a laser cutter.
The result of the acrylic pattern cut is then affixed to the top
of the acrylic engraved with glue.

Two acrylics that have been pasted are then smoothed on
the pieces of the used pieces using emery paper at a
smoothness level of 180, 360, 600, 1200 and 5000 mess.
The refining process is carried out until the cut acrylic part
looks flat and smooth. After the edges of the acrylic are
smooth, acrylic is cleaned using soapy water and then
washed with distilled water then dried.

Then the acrylic was put on a beaker which contained 96%
alcohol as much as 100 ml and then cleaned using ultrasonic
cleaner for 60 minutes. After 60 minutes acrylic is dried
using drayer. Acrylic substrate cleaning is intended to allow
acrylics to be free from materials that are not only able to
be cleaned with water. Clean or not the acrylic substrate affects
the test results of the sample to be coated.

The preparation of SnO2 solution was carried out by
mixing the solvent and SnO2 binder, where ethyl cellulose
([C6H12O5(OH) 3-x (OC2H5) x] n) acted as a binder and
isopropanol (CH3) 2CH (OH) as a solvent from SnO2. The
preparation of this solution was carried out by dissolving
0.13 gr ethyl cellulose and 3 ml isopropanol. Then the
stirring process was carried out using a magnetic stirrer
hotplate for 1 hour with a heating temperature of 50 °C.
The duration of stirring is intended so that the binder and solvent
are completely mixed without any small lumps in the
solution being made. Provision of a heating temperature is
done so that the solution is more easily mixed, noting that
the temperature is used below the melting point of ethyl
cellulose (160 °C-210 °C) and isopropanol (82.2 °C).

After making the solution from the mixture between the
solvent and the perfectly mixed SnO2 binder, then 0.25
grams of nano SnO2 powder are added. Then stirring for 1
hour with a heating temperature of 50 °C using a magnetic
stirrer hotplate. The duration of stirring is intended to allow
the SnO2 powder to dissolve and cannot be distinguished
between solutes and solvents. If the SnO2 solution has
become a gel, the solution is ready to be deposited on an acrylic substrate.

Directional coupler waveguide fabrication is done by coating SnO$_2$ solution on an acrylic substrate. The process of coating SnO$_2$ on an acrylic substrate is carried out by depositing the gel SnO$_2$ solution into the hole in the acrylic channel. When the SnO$_2$ solution is deposited on the directional coupler channel, one of the directional coupler ports is given a multimode optical fiber. The provision of optical fiber in the directional coupler channel aims to make it easier to straighten the laser light beam during the characterization process. Once coated, the acrylic substrate coated with SnO$_2$ is heated to 100 °C above the hotplate stirrer. It aims to remove the solvent used in SnO$_2$ solution, where the melting point for isopropanol is 82.2 °C.

The formed SnO$_2$ film is then coated with an MMA layer. This MMA coating is done 2 times, so that the MMA layer completely closes the SnO$_2$ film. MMA coating serves as a cover on the SnO2 waveguide. Then the heating process at 70 °C for 15 minutes. The heating temperature is maintained so as not to exceed the boiling point of MMA (100 °C). Heating at 70 °C was carried out to polymerize MMA to PMMA.

Testing of SnO2 material transmittance on directional coupler waveguides that have been fabricated is done using Genesys 10S Spectrophotometer UV-Vis. This test is needed to determine the range of wavelengths that are suitable so that light can be transmitted into the SnO2 film properly.

Directional coupler waveguide characterization is carried out by measuring the output of each port from the directional coupler waveguide. Where the He-Ne laser beam is inserted into the optical fiber to propagate into the directional coupler waveguide. Then a photograph of the fabricated cross section of the directional coupler is taken. The directional coupler characterization set up is shown in Figure 2.

III. RESULT AND DISCUSSION

In this study directional coupler has been fabricated with a gap width of 1 point (0.353 mm). The coupling length of the directional coupler of the fabrication result is 5 mm. The fabricated directional coupler is shown in Figure 3.

The fabricated waveguides are characterized by using a He-Ne laser transmitted via optical fiber. The He-Ne laser has a wavelength of 632.8 nm and in the wavelength range of the visible region with red output.

The directional coupler waveguide process begins with taking a cross section of the directional coupler waveguide when given a laser beam. The sketch of the directional coupler waveguide is shown in Figure 4. If B1 is the input, A2, A1 and B2 are outputs and vice versa.

The cross-sectional image for ports A2 B2 and A1 B1 along with the RGB plot of the 5 mm directional coupler waveguide with 5 mm length is shown in Figure 5.
The output values of each port and the percentage of directional coupler waveguide output with a coupling length of 5 mm are shown in Table 1.

<table>
<thead>
<tr>
<th>Input</th>
<th>Output (%)</th>
<th>Output (%)</th>
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<tbody>
<tr>
<td>B1</td>
<td>23.7</td>
<td>21.9</td>
</tr>
<tr>
<td></td>
<td>43.9</td>
<td>26.5</td>
</tr>
<tr>
<td>B2</td>
<td>23.5</td>
<td>49.1</td>
</tr>
</tbody>
</table>

Based on Table 1, it can be seen that for a directional coupler with a combined length (coupling length) of 5 mm has a percentage of output approaching 50%: 25% of the opposite port to the input port is port A1, with a percentage ratio on port B2: A2 that is 49.1%. This difference is caused because not all modes can be moved to the next port (A2) through a gap measuring 0.353 mm or 1 point. When the intensity distribution is observed from the tip of the waveguide, the even mode TE₀ displays one bright spot in the middle, and the even mode TE₁ displays three bright spots. In general, even modes TEₙ display 2n+1 bright spots.

IV. CONCLUSION

From the results of fabrication and characterization of the waveguides that have been carried out, it can be concluded that directional couplers have been successfully fabricated by the sol-gel deposition method and coated with methyl methacrylate (MMA) by the doctor blade method. This directional coupler fabrication can guide He-Ne laser light with a wavelength of 632.8 nm. The output of each directional coupler waveguide port is 26%, 24% and 49%, respectively for ports A1, A2 and B2.

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