Characterization of soda-lime glass with aluminum doping as a planar wave guide using electric-field-assisted solid-state ion exchange method

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Abstract. Characterization of soda-lime has been done with aluminum doping on soda-lime glass using an electric-field-assisted solid-state ion exchange method (EFASSIE) to produce an aluminum coating on the glass. EFASSIE is an ion-exchange method that enables the doping of glass surfaces with aluminum ions. The variations used in ion exchange are temperature and electric fields. Variations of temperature start from 400°C until 500°C, increased temperature will cause the ions inside the glass to vibrate and forming a gap, allowed aluminum ions to penetrate into the glass structure. Variations of electric field start from 300-500 V/mm. Electric field that been exposed to the soda lime glass will accelerate the penetration process of the aluminum ion and pushes the smallest ion out of the glass. The results of the soda-lime glass characterization test shows that the greater the value of temperature and electric field used, refractive index of the soda lime after the ion exchange will increase. Otherwise, glass transmittance after ion exchange process has a relatively small compared to the glass before the process. Soda-lime glass Microstructure after the ion exchange process are known from SEM-EDX test, the result proved that alumunium ion penetrate into the soda-lime glass.

1. Introduction
In the field of communication technology, optical fiber has been widely used as the main medium for data transmission. One of the advantages of using optical fiber in the field of communication is that optical fibers can transmit signals in long distances with low loss power. However, the use of optical fiber also has a weakness in data transmission, this difficulty can be overcome with a planar spray waveguide (planar waveguide). The function of waveguide in optical communication is a very flexible fiber consisting of a dielectric material that looks almost transparent and can carry energy from wavelengths in the infrared, visible, or existing regions of the electromagnetic spectrum [1]. Planar waves consisting of three layers with high indexed film layers are between two low-indexed layers. In the planar waveguide, the substrate layer has a higher refractive index than the cover layer. The basic principle of the planar waveguide is to stimulate the refractive index that occurs on the surface of the film layer. The change of refractive index can be known by using angular coupling mode by knowing the behavior from its angle, for example prism coupling method [2]. The method often used in making waveguide is ion exchange, because this method is simpler and more efficient [3]. In addition, the ion exchange process is the easiest method to produce a glass waveguide with a low power loss [1]. The principle of electric-field-assisted ion exchange method is based on the ion with higher electron polarization so that it has a comparable ion distance value, the refractive index
value will increase and will form a planar waveguide layer [4]. In a process of fabrication using that method, metal ions will be inserted from the metal layer to the glass layer with the help of DC voltage. By using a solid-state process, the experimental configuration can be simple and easy to control the area of possible change [5]. In this case, a characteristic study of soda-lime glass with aluminum doping to be made as a planar waveguide material using electric-field-assisted solid-state ion exchange method.

2. Experimental Methods
The research method used to produce planar waveguide is ion exchange process. The process of doping aluminum to the glass using evaporation or evaporation process using evaporator tool. Evaporation process will produce an aluminum layer on the glass which is then used for ion exchange process. The ions in the glass are forced out and exchanged with aluminum ions present in the aluminum layer.

After getting the result of glass of aluminum-doped soda-lime, then it is treated by ion exchange process based on temperature and electric field variations. The time constant used for the temperature of 500°C is 10.5 minutes and the temperature of 400°C is 9.5 minutes. Variations of electric field values on glass
samples are 500 V / mm, 400 V / mm, 300 V / mm. After the sample through the ion exchange process, the aluminum present in the outermost layer of glass is removed by etching process, i.e., the dissolution of aluminum by using FeCl solution. The etching process is very important to do in order to facilitate the process of characterization.

The characterization had been using SEM-EDX test to see the microstructure of glass after ion exchange process, measure the change of refractive index value and the value of transmittance. It also aims to find out whether aluminum ions can fit properly into components present in the glass.

3. Result and Discussion

The SEM-EDX test results that have been done indicate that aluminum ions can be incorporated into the glass composition. This can be seen in Figure 3.

![Figure 3. SEM-EDX test results: Spectrum of soda-lime glass after ion exchange process.](image)

![Figure 4. Graph of refractive index change of soda-lime glass to electric field change (V / mm).](image)

The SEM-EDX spectrum data shows that aluminum ions can enter into glass compositions using the EFASSIE method. This proves that the method has succeeded in producing aluminum doping on soda-
lime glass. Given the change in the composition of the glass, this results in a characteristic change of the glass. The change of characteristic can be seen from the change of refractive index value and its transmittance value.

The result of characterizing the measurement of refractive index values on the glass shows that the greater the temperature used, the change of refractive index value of glass after ion exchange process tends to increase. Increasing of temperature and electric field may affect the movement of ions present in the glass to allow for aluminum ions to enter the glass and exchange with Na+ ions present in soda-lime glass. This can be seen in Figure 4.

![Figure 4](image)

**Figure 4.** Graph of refractive index value at wavelength 300-900 nm.

The increasing in refractive index value is one of the requirements of making planar waveguides. The result of measurement of transmittance value on glass sample after ion exchange process has relatively smaller value compared to glass before ion exchange process. This is influenced by the absorption of light on the glass so that the transmittance value is reduced or smaller. The more aluminum ions that enter the glass will make the value of the intensity of the outgoing light decreases.

4. Conclusion

From the results of this study can be obtained that the results of aluminum doping has been proven to enter into the composition of glass. This also caused a change in refractive index values on the glass that tends to increase and decrease the value of transmittance due to the absorption of light into the glass. It can be concluded that after the ion exchange process the glass composition changes with the addition of aluminum ions.

5. References

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