A study of the optical transmission spectra of polyester resin-based glass fabricated by open mold cast technique

F Wahyuni 1*, D J D H Santjojo 1, U P Juswono 1, D R Santoso 1, and S P Sakti 1*

1Physics Department, Brawijaya University, Jl. Veteran 65145 Malang, East Java, Indonesia

*Corresponding author’s e-mail address: fwahyuni@gmail.com; sakti@ub.ac.id

Abstract. Polyester resin is a thermoset resin commonly used in the production of polymer composites. Polyester resin is a polymer matrix that is easily available and widely used by the general public and industry. Besides, this resin is cheap, has unique characteristics, namely that it can be made rigid and flexible. This research aimed to investigate the optical transmission spectra of polyester resin-based glass fabricated by open mold casting technique with different MEKPO or methyl ethyl ketone peroxide concentrations in the visible region. This research used Yukalac C 108B polyester resin. Catalyst MEKPO was added with three variations, 1%, 2%, and 5%. The prepared mixture was then set at 30 Celsius degree and 1000 RPM for five minutes by a magnetic stirrer. The optical transmission spectra of the glass were measured using optical emission spectroscopy. The result shows that the optical spectra of this polyester resin-based glass possess higher transmission in the region at 650 nm to 700 nm and the amount of catalyst that can produce polyester resin glass material by open mold cast technique with higher optical properties at 1% catalyst composition.

1. Introduction
Composite materials are one of the most important discoveries in materials science [1-2]. Various polymers such as thermoplastics, thermosets, and elastomers have been used as matrix materials with different metals or metal compounds as fillers during the manufacture of polymer composites [3]. Polymer composites find their place in areas such as biomedicine, automotive, aerospace, construction applications, electrical and electronics fields, health care applications, sports, and many more. The main advantages of using a polymer as a matrix are low cost, easy processing, good chemical resistance, low density, and lightweight [3–5]. Polyester resin is a thermoset resin commonly used in the production of polymer composites [6]. Polyester resin is used as a transparent liquid that transforms into a solid-state after adding the hardener [7]. Unsaturated Polyester is the most widely used resin, from the most basic until the process with machines [8]. Polyester resin can be used as a matrix of glass substitutes. Some amorphous and glassy polymers are molded into optical devices [9].

When fabricating using polyester resin, ensure that the resin and catalyst are evenly distributed. In the stirring process, no air is trapped in the composite solution. So that it will cause the mechanical properties of the composite material to be significantly reduced. Then the catalyst application must also be considered, too much catalyst will result in the hardening process too fast whereas if too little composite is formed it will be under-cured.

Based on the above description, it is necessary to investigate the optical transmission spectra of polyester resin-based glass fabricated by open mold casting technique with different MEKPO or
methyl ethyl ketone peroxide concentrations in the visible region, so know the effect of the catalyst composition on the optical transmittance spectra of polyester resin-based glass. The transmittance is the ratio of the intensity of the light that has passed through the sample to the intensity of the light when it entered it [10-11]. Transmittance refers to the percentage of radiation that can pass through glazing. Glass is a fusion product of inorganic material which has been cooled to a rigid condition without crystallization [12]. Transmittance can be defined for different types of light or energy [13-14]. Transmittance is the relationship between the amount of light that is transmitted to the detector once it has passed through the sample \( I \) and the original amount of light \( I_0 \) [15]. Transmission of visible light determines the effectiveness of a type of glass in providing daylight and a clear view through the window. The human eye is sensitive to light at wavelengths from about 0.4 to 0.7 microns [16]. With this research, it is expected to produce polyester resin-based glass which has the power transmittance of more than 80%. Transmittance was investigated using a spectrophotometer (Aurora 4000) in the range of 400 to 700 nm. Relation the transmittance to intensity defined by the following equation:

\[
T = \frac{I}{I_0}
\]  

(1)

The power transmittance [%] of the glass is calculated by the following equation:

\[
\text{Power transmittance} \% = \left[ 1 - \frac{|I - I_o|}{I_0} \right] \times 100\%
\]  

(2)

where \( I_0 \) is the light intensity before passing the glass and \( I \) is the light intensity after passing the glass [15].

2. Methods

2.1. Materials

The unsaturated polyester resin was used as a matrix in the composite. YUKALAC 108B unsaturated polyester (UP) resin and Methyl ethyl ketone peroxide (MEKPO) was purchased from Brataco Chemika PT, Indonesia. The UP has density 1.215 g/cm³, melting point 170 Celsius degree, water absorption 0.118% (24 hours), tensile strength 5.5 kg/mm², modulus of elasticity 300 kg/mm² and elongation at break 1.6%. The polyester precursor will set by itself if enough time is given. But, for practical purposes, this rate of polymerization is too slow. Hence, a suitable catalyst is being added to achieve the process of polymerization within the stipulated time.

2.2. Fabrication of Polyester Resin-Based Glass

The polyester resin-based glass was fabricated with by open mold cast technique. The first step, making a mold from silicon rubber which is formed into open cubes. The dimension of the mold was 4 x 4 cm² of 0.5 cm thick. Methyl ethyl ketone peroxide was added to polyester with variations composition of 1%, 2%, 5%. Magnetic stirring from these samples is carried out to make a homogeneous mixture of methyl ethyl ketone peroxide and polyester. The magnetic stirrer is set to rotate at 30 Celsius degree and 1000 RPM for five minutes. After uniform dispersion, polyester and methyl ethyl ketone peroxide mixture are poured evenly into the mold, and then the polyester resin-based glass is kept followed it uniformly to remove the void with the help of a spatula. The same procedure is repeated until all parts of the mold are filled. The mold is not covered and after this step, the mold is left for 5 hours at room temperature for curing, and then the sample is removed from the mold.

2.3. Measurement of Optical Transmission Spectra
The optical transmission spectra of the polyester resin-based glass of equal thickness (5 mm) were recorded at room temperature by using the optical emission spectroscopy (OES) (Aurora 4000) GE-UV-NIR in the visible region. The optical transmission spectra of the glass have been observed in the visible region (400 to 700 nm). The diagram of the transmission measurement method is given in Figure 1. The method used in this study is to measure the light transmission value before the sample, then by providing the same light source to each sample to obtain the light transparency value of each tested sample shown on the OES tool. The sample is placed in the box and the box is closed when making light transmission measurements.

![Figure 1. Set-up of the optical transmission spectra measurement.](image)

3. Results and Discussion
The testing of polyester resin-based glass on the ability to transmit light was conducted. Measurement of light transmission in each sample was carried out using an LED lighting source with optical emission spectroscopy (OES) light transmission gauge. The results of the light transmission measurement can be shown in Figure 2.

![Figure 2. The optical transmission spectra of polyester resin-based glass fabricated by open mold cast technique samples at room temperature.](image)

Based on the graph in Figure 2, it shows a decreasing intensity values related with the addition of methyl ethyl ketone peroxide. The sample of 5% becomes the lowest intensity sample. In general, it can be stated that the greater the catalyst content, the faster the chemical reactions that occur. At the 5% catalyst condition, it can be assumed that the reaction takes place very quickly so that when molding, the resin begins to thicken and the surface tension is high so that the adhesion and adsorption that occurs is less strong.
Table 1. The relation between the concentrations and the intensity of polyester resin-based glass.

| MEKPO concentrations | The intensity of polyester resin-based glass (a.u) |
|----------------------|--------------------------------------------------|
|                      | $\lambda$ 430 nm | $\lambda$ 450 nm | $\lambda$ 500 nm | $\lambda$ 550 nm | $\lambda$ 600 nm | $\lambda$ 650 nm |
| Without sample       | 6770             | 15068            | 5507             | 10770            | 7929             | 3218             |
| 1%                   | 5794             | 13718            | 5226             | 10141            | 7552             | 3116             |
| 2%                   | 5740             | 13132            | 4896             | 9468             | 6963             | 2887             |
| 5%                   | 5638             | 12916            | 4780             | 9340             | 6876             | 2860             |

The variation of the methyl ethyl ketone peroxide concentrations affects the intensity of polyester resin-based glass. Table 1 is the intensity result of polyester resin-based glass at various the methyl ethyl ketone peroxide concentrations. It can be shown from the table that a lower concentration for methyl ethyl ketone peroxide results increase the intensity of polyester resin-based glass. The intensity of the transmitted light depends on the position of the sensor, the position of the sample, and the power of the light source [17-18].

Figure 3. The transmittance of polyester resin-based glass fabricated by open mold cast technique.

From Figure 3, it can be seen that the light transmission value that is transmitted after passing through the polyester resin sample decreases the light transmission value along with the increasing concentration of methyl ethyl ketone peroxide. The highest light transmission value in the region is at 650 nm to 700 nm at a concentration of 1% methyl ethyl ketone peroxide, and the lowest light transmission value was at a 5% methyl ethyl ketone concentration. This shows that with increasing concentrations of methyl ethyl ketone concentration, the resulting light transmission value decreases, influenced by the greater the light absorbed by the sample.

Table 2. The power transmittance at the various concentrations of methyl ethyl ketone peroxide.

| Power Transmittance (%) |
The power transmittance changes according to changes in the concentration of methyl ethyl ketone peroxide used (as shown in Table 2). The results of this study indicate a relationship between the use of methyl ethyl ketone peroxide concentrations with power transmittance. The greater the methyl ethyl ketone peroxide concentration used, the smaller the power transmittance value produced. When using methyl ethyl ketone peroxide 1%, the resulting power transmittance is 85% at around 430 nm. The power transmittance value decreased when the methyl ethyl ketone peroxide concentration was higher. The use of 2% methyl ethyl ketone peroxide resulted in a power transmittance of 84% at around 430 nm and the highest concentration of methyl ethyl ketone peroxide, which was 5%, resulting in a power transmittance of 83%.

| Wavelength (nm) | Concentrations of methyl ethyl ketone peroxide |
|-----------------|-----------------------------------------------|
|                 | 1%    | 2%    | 5%    |
| 430             | 85    | 84    | 83    |
| 450             | 91    | 87    | 85    |
| 500             | 94    | 88    | 86    |
| 550             | 94    | 88    | 87    |
| 600             | 95    | 88    | 87    |
| 650             | 96    | 89    | 87    |

**Figure 4.** The power transmittance spectra of polyester resin-based glass fabricated by open mold cast technique.

The power transmittance spectra of polyester resin-based glass fabricated by open mold cast technique samples at room temperature are shown in Figure 4. From the results obtained, it can generally be said that the concentrations of methyl ethyl ketone peroxide significantly affect the composite optical properties. Polyester resin glass can transmit > 80% of visible light. Thus, the polyester resin-based glass fabricated by open mold cast technique has a good light transmission ability because it can pass the amount of light it receives. The higher the transmission level, the more light will be transmitted, vice versa, the lower the transmission level, the less light will be transmitted.

4. **Conclusion**

The changes in the concentration of methyl ethyl ketone peroxide affects the transmittance of polyester resin-based glass fabricated by an open mold cast technique. A higher the concentration of methyl ethyl ketone peroxide used, a smaller the transmittance value. Polyester resin glass can transmit more than 80% of visible light. The optical spectra of this polyester resin-based glass possess a higher transmission in the regime of 650 nm to 700 nm and the amount of catalyst that can produce polyester resin glass material by open mold cast technique with a higher optical properties at 1% catalyst composition.
5. References

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