Optical properties of wood by laser spectroscopy

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Abstract. Optical properties of three Indonesian woods (Red Jabon, Kapur and Red Meranti) has been analyzed based on its photoluminescence (325 nm and 405 nm), reflectance and absorbance spectra. The sample thickness affected to the emission spectra. We found that lignin and cellulose were emitted around the UV (400 nm-500 nm) and visible (500 nm-600 nm) wavelength respectively. The amount of lignin exist in the wood are 25.68% for Red Jabon, 14.57% for Kapur and 27.93% for Red Meranti. This method shows high potentials for determining lignin for any kind of woods.

1. Introduction

Wood is one of material that commonly find in daily life. The product of wood can be house hold kit, handicrafts, furniture, pulp, fibers, and films [1], biomaterials [2-3] and so on. This makes several of researches in science and technology focusing wood as the main study object [4-7].

From the chemical point of view, every wood has cellulose, hemicellulose, lignin, water content and extractive substance [8]. Commonly, play the dominant role in wood photoluminescence is the presence of lignin [9-11]. Cellulose was characterized by chemical treatment for eliminate the other compound like fat, protein, pectin and wax [1].

Optical Properties of wood can be analyzed by their interaction with light. Luminescence is one of the optical Properties of wood caused by interaction of chemical compound while excited by laser spectroscopy. Because of the wood emission is very weak to visualized, filter is needed to fade the influence of the laser. Lignin and cellulose were emitted around the UV [8-9, 16] and visible wavelength [17-18]. According to Ref. [17, 19] the emission spectra influenced by excitation wavelength, water content, and chemical treatment.

In this research, we reported the optical properties by varying the excitation wavelength without any chemical treatment for analyze lignin and cellulose emission spectra in the Tangential (T) direction of the wood samples.

2. Experiment

2.1 Material

Three wood samples are Red Jabon (*An tho cephalus macro phyllus (Roxb.) Havil*), Kapur (*Dryobalanops beccarii* Dyer), and Red Meranti (*Shorea ovalis* (Korth.)). The wood dimension consist of radial (R) x tangential (T) x longitudinal (L) as shown in the figure 1 and the size of the wood samples were shown in the table 1.

| Table 1. Size of wood samples |
|-----------------------------|
| Wood samples | Radial (cm) | Tangential (cm) | Longitudinal (cm) | Thickness (cm) |
| Red Jabon (JM) | 1.35 | 1.30 | 1.65 | 1.35 |
| Kapur (K) | 1.85 | 1.70 | 2.20 | 1.50 |
| Red Meranti (MM) | 1.50 | 1.50 | 1.75 | 1.20 |
2.2 Characterization

The Photoluminescence (PL) Spectroscopy was used for analyzing the emission spectra of the wood samples. Pico laser with excitation wavelength 405 nm for cellulose emission and femtosecond laser (Spitfire Ace) with excitation wavelength 325 nm for lignin emission. The Reflectance Spectra of the samples are determined by Reflectance Spectroscopy. The absorbance spectra is calculated using the following formula:

\[
\text{Absorbance} = -\log_{10}(R)
\]

Where R is the reflectance data, respectively [20].

3. Results and discussion

3.1 Optical Properties of Photoluminescence Spectroscopy

The PL emission spectrum with excitation wavelength 405 nm used to find out cellulose emission of wood shown in figure 2. Figure 2a shown K’s emission spectra at a wavelength 550 nm, JM’s emission spectra at wavelength 554 nm, and MM’s spectra at a wavelength 448 nm was the highest intensity. The difference of intensities influenced by the absorption of wood molecules. Every wood has its own absorbance region because of its different composition. Figure 2b clearly shows a shift in emission wavelength peaks in the samples while excited by laser with wavelength 405 nm, its caused by the spread of cellulose molecules that are not evenly distributed on the surface of the wood [1]. The result of emission peak with laser excitation wavelength 405 nm was the same as the previous study [18].

![Figure 2. PL Spectra with excitation wavelength 405 nm.](image-url)
Figure 3. PL Spectra with excitation wavelength 325 nm.

Figure 3 shown PL spectra with excitation wavelength 325 nm. Figure 3a shown the higher emission intensity is MM’s spectra at wavelength 484 nm with intensity 1187 a.u. The lower intensity is K’s emission spectra 445 a.u. but it has the higher emission wavelength 550 nm. The JM’s emission at wavelength 520 nm with emission intensity 1064 a.u. Figure 3b also shows a shift in emission wavelength peaks in the samples while excited by laser with wavelength 325 nm, its caused by the spread of the lignin and cellulose molecules that are not evenly distributed on the surface of the wood [1]. As we can see, the figure 2 and 3 shown the sample thickness greatly affects the emission spectra, the thicker sample has the higher emission intensity [21].

Figure 4. PL Spectra with multi-peaks Gaussian fitting.

To analyze the lignin emission spectra, we used the multi-peaks Gaussian fitting. Figure 4 shown the wavelength range between the two peaks virtually identical. The lignin emission wavelength and the
cellulose emission wavelength of Red Jabon, Kapur and Red Meranti are 472 nm and 561 nm, 464 nm and 567 nm, 463 nm and 551 nm. Based on the fitted graphs, we can measure the percentage amount of the lignin and cellulose in every wood. The percentage shown in the table 2. The higher percentage of lignin and cellulose are Red Meranti 27.93% and Kapur 85.43%.

Table 2. Percentage of lignin and cellulose in the wood samples.

| Wood Sample   | Percentage (%) | Lignin  | Cellulose |
|---------------|----------------|---------|-----------|
| Red Jabon     | 25.68          | 74.32   |
| Kapur         | 14.57          | 85.43   |
| Red Meranti   | 27.93          | 72.07   |

3.2 Optical Properties of Reflectance Spectroscopy

Optical properties of wood when fiber probe holder touch the sample surface and the light reflected back called reflectance properties. The orientation of optical fiber and wood structure influenced the light absorbed spectra [8]. Figure 5 shown reflectance spectra of the wood samples in wavelength range 250 nm until 900 nm, around the wavelength 400 nm started bumpy and being saturated at 800 nm. Based on the reflectance data, the absorbance can be calculated by using equation (1) as shown in the figure 6.
Figure 6. Absorbance Spectra based on figure 5 data.

Figure 6 shown the absorbance spectra of the wood samples in wavelength range 200 nm to 1100 nm but it absorbance effectively at wavelength 350 nm and started saturate at 770 nm. In the figure 6 also shown the peak shifted, the absorbance peak of MM, JM, and K wood are 307 nm, 342 nm, and 315 nm. The range of absorbance peak also listed in Ref. [15].

4. Conclusion
Optical properties of wood is emitted when excited by laser and visualize by filter. The result of photoluminescence with excitation wavelength 405 nm and 325 nm shown lignin emitted effectively in the UV wavelength and cellulose emitted in the visible wavelength. The absorbance properties of wood absorbed effectively at wavelength 350 nm and started saturate at 770 nm.

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