Characterization of Natural Dye from Papaya Leaf as Sensitizer for Solar Cell Applications

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Abstract

In this research, natural dyne of chlorophyll extracted from papaya leaf is used as sensitizer to fabricate dye sensitized solar cell (DSSC). Extracting solvent from hot water and methanol are used to observe the most effective method and dye ability. UV-Vis measurement is carried out to observe the optical properties of papaya extract. From UV-Vis absorption spectrum, band gap energies are investigated.

1. Introduction

Solar electricity is a steadily growing energy technology today and solar cells have found markets in variety of applications ranging from small-scale electronic devices to large scale power plants. A dye sensitized solar cell is a low cost cell belonging to the group of thin film solar cells. The dye plays a key role as a sensitizer in absorbing and transforming sunlight solar energy into electric energy. Natural dyes found in flowers, leaves, and fruits which resemble organic dye can be extracted by simple procedures. In this research, natural dye is extracted from papaya leaves [1][2]. Papaya leaves chemical profiling have been shown so many active components such as papain, chymopapain, cystatin, tocopherol, ascorbic acid, flavonoids, cyanogenic glucoside and glucosinolates as shown in figure 1. Chemical structure and chemical composition of papaya leaf are shown in figure 2 and Table 1 [3].

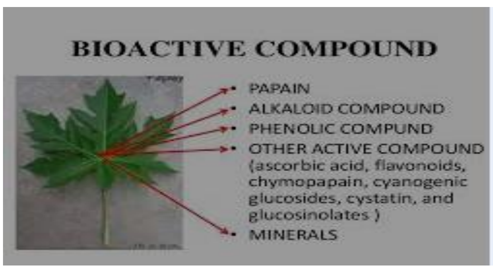


Figure 1. Bioactive compound of papaya leaves

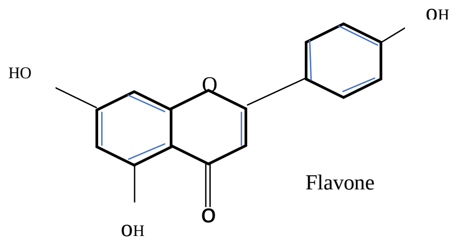


Figure 2. Chemical structure of flavonoid

Table.1. Chemical composition of papaya leaves

Composition		Composition	
Energy (cal)	79	Vitamin B (mg)	0,15
Water (g)	75,4	Vitamin C (mg)	140
Protein (g)	8	Calcium (mg)	353
Fat (g)	2	Iron (mg)	0,8
Carbohydrate (g)	11,9	Phosphor (mg)	63
Vitamin A (IU)	18,25		

2. Material and Methods

The collected leaves are washed with distilled water to remove dust and impurities. These leaves are dried for 4 days at room temperature and cut into smaller pieces. They are ground with agate motor. After grinding, 5g of papaya leaves are weighted the beaker as shown in figure 3. Firstly, they are mixed with 50ml of hot water and methanol respectively. These solutions are stirred with magnetic stirrer at 30°C and 60°C for 45 min as shown in figure 4. And then, the papaya dye solutions are cooled down at room temperature. The dye extraction is filtered using filter paper to remove solid residues as shown in figure 5. Finally, the extracted dye solutions are put into sample holder. The optical properties of dye solutions are analyzed by UV-Vis-NIR spectrophotometer [4][5][6].

Figure 3. Photograph of weight starting of papaya leaves powder

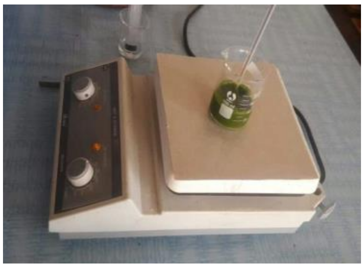


Figure 4. Photograph of papaya solution are heated and stirred with magnetic stirrer

Figure 5. Photograph of the filtration of papaya solution

3. Results and Discussions

Figure 6 shows photograph of the SHIMADZU UV-1800 spectrophotometer. The optical absorbance spectra of papaya leaves are mixed with 50ml of hot water and methanol samples, are collected in UV-Vis-NIR region (190 nm – 1100 nm) by using UV-1800 UV-Vis-NIR spectrophotometer as shown in figure 7(a-d). In the present work, all absorption peaks are ranged in visible light region. The energy band gap of samples are calculated from the absorption by direct method ($E = \frac{hc}{\lambda}$) as shown in Table 2 [7]. The energy band gap of papaya leaves is mixed with 50ml of hot water and methanol samples are less than 3 eV. Figure. 8(a -d) show optical transmittance spectra of papaya dye extracted with different solvents at different temperature. Theory of optical absorption gives the relationship between the absorption coefficient α and the photon energy has a relation;

$$\alpha = 2.303\frac{A}{t}$$

Figure.9(a-d) show the plot of the variation of $(\alpha h\nu)^2$ with the photon energy hν of samples. The average energy band gap of samples is determined from the intercept of linear portion of the $(\alpha h\nu)^2$ vs $h\nu$ graph as shown in Table 3. According to these values, papaya dye may be used as a dye sensitizer for dye sensitized solar cell [8]. This confirms the successful extraction of the dyes with the presence of chlorophyll suitable enough for absorption of visible light [9] [10].

Figure 6. Photograph of UV-Vis-NIR spectrophotometer

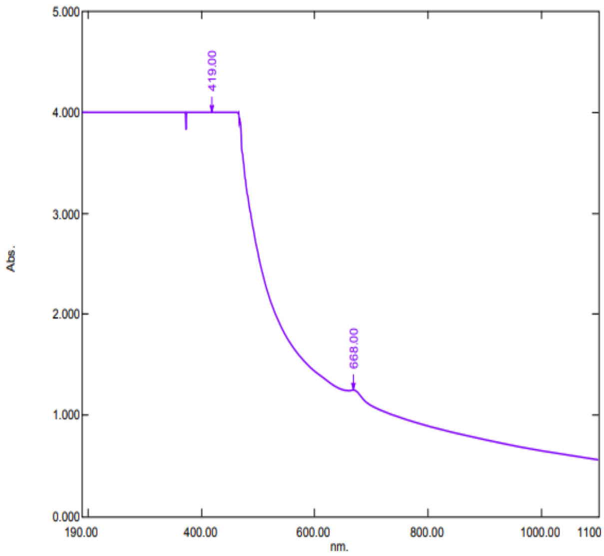


Figure7(a). UV-Vis-NIR optical absorbance spectrum of papaya (30 ºC) (45min) (Hot Water)

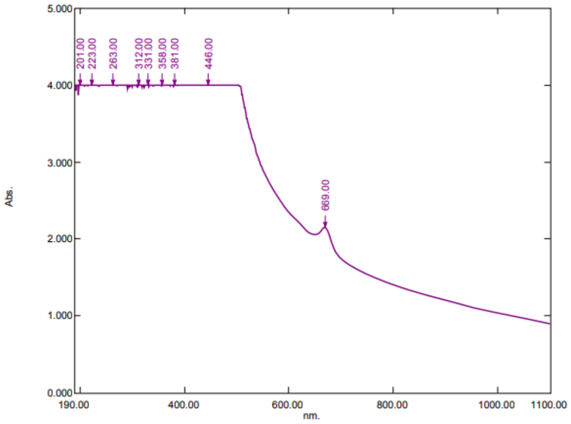


Figure 7(b). UV-Vis-NIR optical absorbance spectrum of papaya (60 °C) (45min) (Hot Water)

Table 2. Band gap energy values derived from direct method.

solvent	Cutoff wavelength (nm)		Band gap energy (eV)	
	30°C	60°C	30°C	60°C
Hot water	559.04	650.47	2.208	1.897
Methanol	483.33	605.41	2.550	2.039

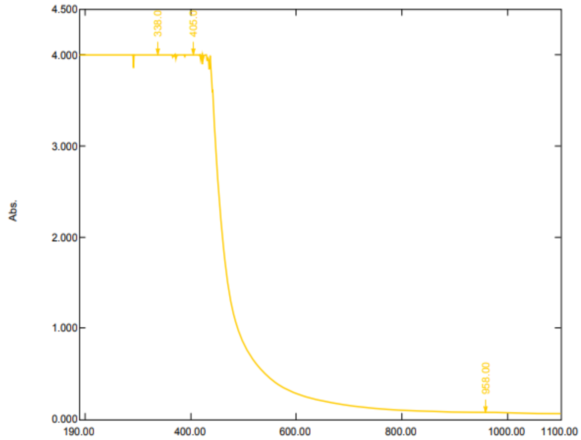


Figure 7(c). UV- Vis -NIR optical absorbance spectra of papaya (30°C) (45min) (Methanol)

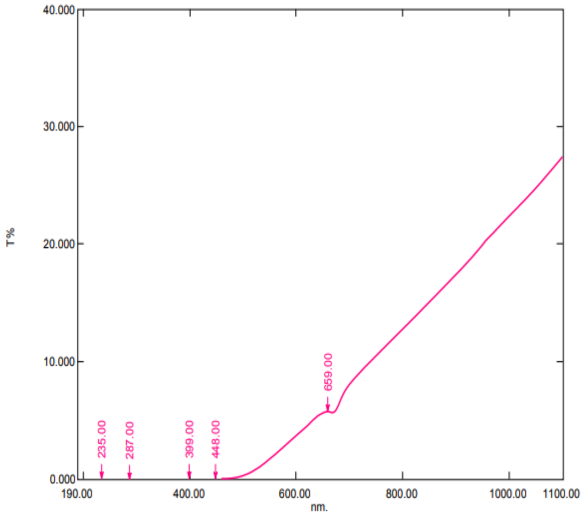


Figure 8(a). UV- Vis -NIR optical transmittance spectrum of papaya (30°C) (45min) (Hot Water)

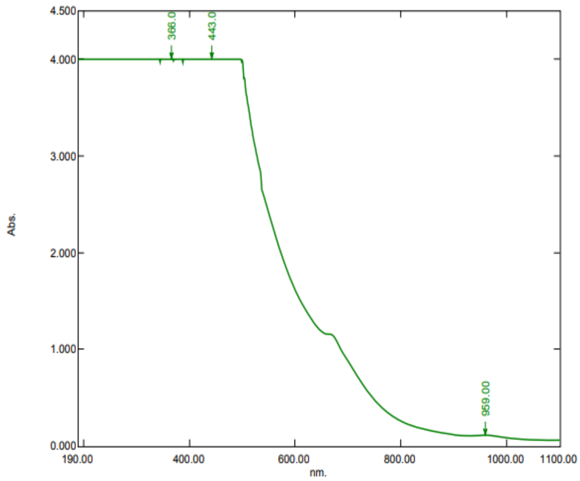


Figure 7(d). UV- Vis -NIR optical absorbance spectra of papaya (60°C) (45min) (Methanol)

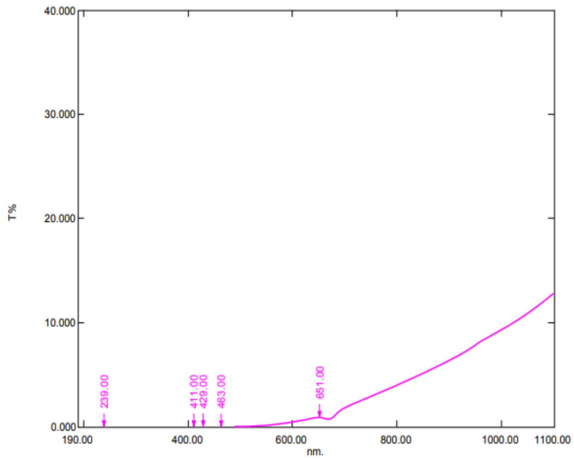


Figure 8(b). UV- Vis -NIR optical transmittance spectra of papaya (60°C) (45min) (Hot Water)

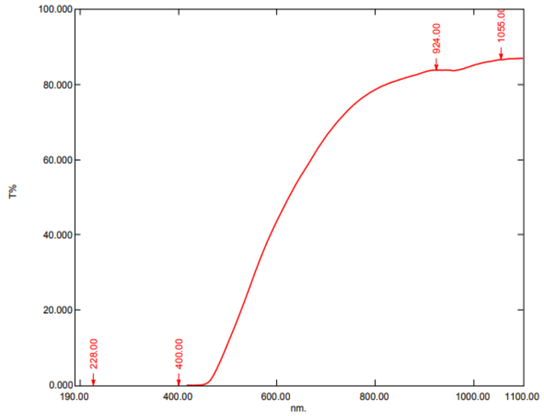


Figure 8(c). UV-Vis-NIR optical transmittance spectra of papaya (30°C) (45min) (Methanol)

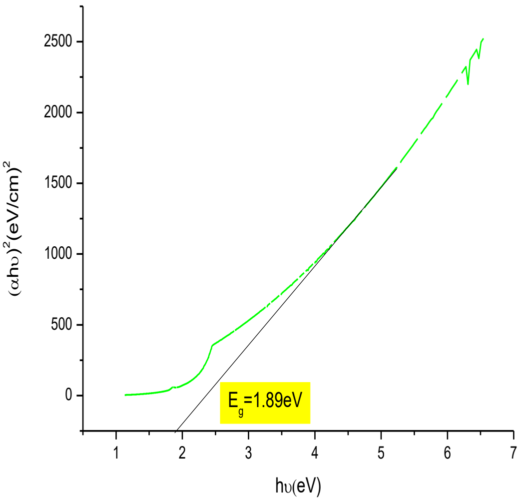


Figure 9(b). Plot of the $(\alpha h\nu)^2$ vs hν graph of papaya (60°C) (45min) (Hot Water)

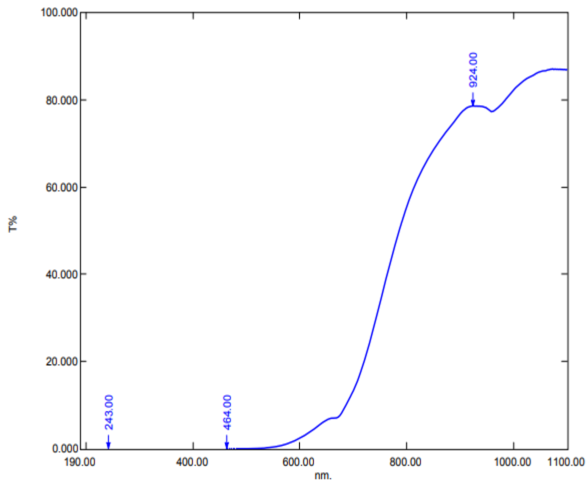
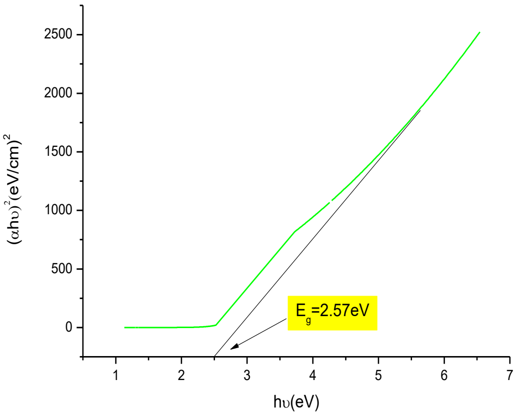


Figure 8 (d). UV-Vis-NIR optical transmittance spectra of papaya (60°C) (45min) (Methanol)



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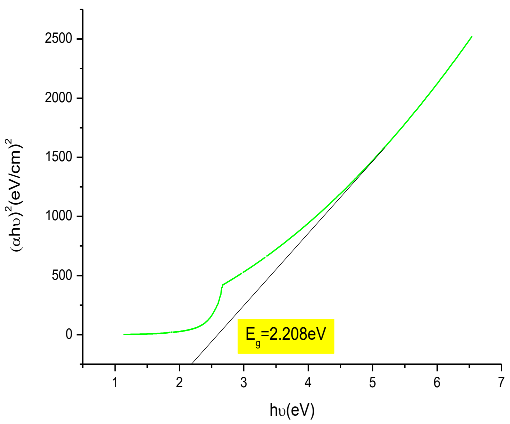

Figure 9(a). Plot of the $(\alpha h\nu)^2$ vs hν graph of papaya (30°C) (45min) (Hot Water)

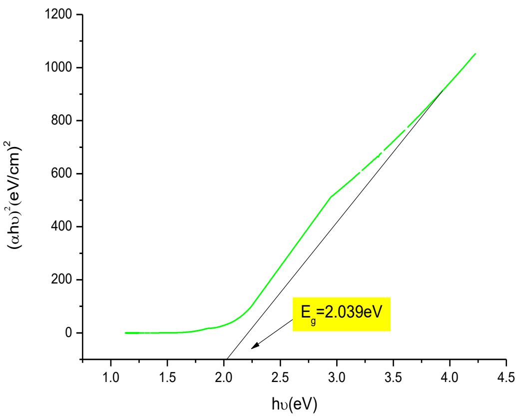

Figure 9(d). Plot of the $(\alpha h\nu)^2$ vs hν graph of papaya (60°C) (45min) (Methanol)

Table 3. Band gap energy values derived from Tauc method

solvent	Band gap energy (eV)	
	30ºC	60ºC
Hot water	2.208	1.890
Methanol	2.570	2.039

4. Conclusions

The optical properties of papaya extracted with different solvents at different temperatures have been investigated. The band gap energy of natural dyes extracted from papaya leaves are observed by two methods such as direct and Tauc methods. The energy band gap values from different methods are found to be significantly different. The optical band gap is found to vary in the range of 1.897 to 2.570 eV. According to these values, papaya dye may be used as a dye sensitizer for dye sensitized solar cell. Hence, the energy band gap of dye with hot water for 60 ^{o} C is 1.897 eV by direct method and 1.890 eV by Tauc method. And also, it is significantly observed that hot water is more feasible for papaya dye extraction. These dyes are said to be cost effective and easy to be prepared. The experimental data from the research, papaya dye is credible and applicable for dye sensitizer.

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[10]*https://www.instanano.com/characteristization/theoretical/uv-vis spectroscopy-band-gap-calculation/*