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Optical absorption in recycled waste plastic polyethylene

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Abstract. We investigated the optical properties of UV spectrum absorption in recycled waste plastic from polyethylene polymer type. Waste plastic polyethylene showed an optical spectrum absorption after its recycling process. Spectrum absorption is determined using spectrophotometer UV-Nir Ocean Optics type USB 4000. Recycling method has been processed using heating treatment around the melting point temperature of the polyethylene polymer that are 200°C, 220°C, 240°C, 260°C, and 280°C. In addition, the recycling process was carried out with time variations as well, which are 1h, 1.5h, 2h, and 2.5h. The result of this experiment shows that recycled waste plastic polyethylene has a spectrum absorption in the ~340-550 nm wavelength range. The absorbance spectrum obtained from UV light which is absorbed in the orbital n → π * and the orbital π → π *. This process indicates the existence of electron transition phenomena. This mechanism is affected by the temperature and the heating time where the intensity of absorption increases and widens with the increase of temperature and heating time. Furthermore this study resulted that the higher temperature affected the enhancement of the band gap energy of waste plastic polyethylene. These results show that recycled waste plastic polyethylene has a huge potential to be absorber materials for solar cell.

1. Introduction

Solar energy has been highly considered since previous time to be used as an alternative renewable energy [1-2]. The energy of solar light provides electrical energy through its conversion using solar cell devices [3-4]. Solar cell device—Dye-Sensitized Solar Cell (DSSC)—absorbs sunlight using dye material to produce electrons. These electrons then injected into semiconductor materials such as titanium dioxide (TiO2) and zinc oxide (ZnO). The electrons will flow throughout transparent conductive oxide (TCO) to the external circuit and to the counter electrode. Afterward the electrolyte returns the electrons to the dye molecule and creates whole series of processes continue to form a cycle [5]. In this case these electrons specifically perform to convert solar light energy into electrical energy. According to the whole processes, dye material has an essential role to absorb sunlight and to produce electron excitation process. Dye has a high absorption characteristic over a wide wavelength range so that it is rich of excitation electrons released by photon from sunlight.
Some number of dye material have been extracted from natural resources including dragon fruit, banana bud, roses and spinach which have chlorophyll pigments, carotene, anthocyanin and flavonoids [6-8]. The functional groups of carbon chains within those pigments have a very high potential to be dye material due to its optical absorption region of sunlight. The functional groups—that have a role in absorbing photons from ultraviolet (UV) rays—are carbonyl-chromophores (—C=O) and alkenes (—C=C) [9]. Those functional groups were being found in a variety of natural materials. Moreover the presence of these carbon groups can be found abundantly in some types of polymers [3]. Polymer contains long chain of united-carbons. The study to investigate the potential of polymers as a material that absorbs photons from UV rays is remains rare. Several types of polymers with hydrophobic and nonpolar properties are advantageous when compared to the natural dye which is easily soluble. The main concern of DSSC is the decline in long time stability due to the dye degradation caused by interaction with external components such as oxygen and water [10].

Solid polymers were used and developed as dye to minimize the solubility and maintain the stability. Plastic is very popular products rich of polymer materials. Various types of plastics can be classified according to the basic materials such as from polyethylene polymer type (C2H ¬ 4). Polyethylene is widely used to produce plastic bags and bottles of drinking water. The existence of abundant long chain of carbon in plastic waste from polymeric polyethylene i.e. 85% carbon element is high potential for recycling. The methyl group of polyethylene polymers can be easily oxidized by heating process. This process creates carbonyl functional group to absorb photon from sunlight. Recycling waste plastic polyethylene using heating process is becoming the focus of this research. Optical absorption has been analyzed to see the potential of plastic waste as a base material that capable in absorbing UV rays from sunlight.

2. Methods
Waste plastic polyethylene simply obtained free from the environment and cleaned from the impurities before the next process. The process of recycling waste plastic polyethylene was using heating treatment at the temperature around the boiling point i.e. T = 260°C for 1 h, 1.5 h, 2 h, and 2.5 h. Sample result of this process then analyzed the optical absorption using a VIS-NIR Ocean Optics type USB 4000 spectrophotometer device. The analysis of optical absorption spectra can be used to estimate band gap energy with Tauc plot by following Equation 1.

\[(\alpha h \nu)^2 = h \nu - E_g\]  

(1)

with \(\alpha\) as an absorption coefficient, \(h\) is Planck's constant, \(\nu\) is frequency and \(E_g\) is a band gap energy. Band gap energy can be estimated when the abortion coefficient is zero so that the value of the intercept represents the band gap energy.

3. Result and Discussion
The optical absorption of recycled waste plastic polyethylene changes compare to the waste plastic without heating treatment as shown in Figure 1. The recycled waste plastic polyethylene which was synthesized at temperature T = 260°C for 1 h, 1.5 h, 2 h and 2.5 h has an absorption spectra at wavelength of 350-550 nm. Waste plastic polyethylene with no heating process does not have the absorption spectra. This shows that waste plastic polyethylene is highly potential to absorb photons. The absorption spectra indicate the existence of an electronic transition mechanism. This mechanism defines as the displacement electrons from the orbital bonding to the orbital anti-bonding. Microscopically, the heating process causes the methyl functional group has oxidized to form a carbonyl group capable to absorb an electromagnetic wave radiation such as UV light [11]. The longer heating time on recycling waste plastic polyethylene leads to produce more carbonyl groups. It creates the enhancement and the wide intensity of absorption spectra.
The alteration of optical absorption in waste plastic polyethylene due to heating process occurs due to structural changes in carbon chain bonds. The double bond of C = O formed by the oxidation shows that the transition electronics occur in the $\pi \rightarrow \pi^*$ orbitals. The estimation of the energy difference in a fully charged orbital of high occupied molecular orbital (HOMO) electrons and the orbitals without electrons or lowest unoccupied molecular orbital (LUMO) is done by analyzing the absorbance spectra of Figure 1. The energy difference between HOMO and LUMO for waste plastic polyethylene which is heated for 1 h is shown in Figure 2.
Figure 2. Absorption coefficient of waste plastic polyethylene synthesized for 1h.

Table 1. Distribution of band gap energy with time variation at temperature 260°C.

| Time (h) | Energy (eV) |
|---------|-------------|
| 1.0     | 2.31        |
| 1.5     | 2.72        |
| 2.0     | 2.73        |
| 2.5     | 2.50        |

Table 2. Distribution of band gap energy recycled for 1 hour with variation of heating process.

| Temperature (°C) | Energy (eV) |
|------------------|-------------|
| 200              | 2.22        |
| 220              | 2.25        |
| 240              | 2.35        |
| 260              | 2.70        |
| 280              | 2.70        |

The higher temperatures resulted to the larger of the band gap energy. Waste plastic polyethylene has 2.22 eV heated at temperature of 200°C and 2.25 eV at temperature of 220°C. Band gap energy increased for 0.03 eV heated from 200°C to 220°C. It also increases for 0.1 eV and 0.45 eV heated from 220°C to 240°C and 240°C to 260°C respectively. Even though band gap energy remains 2.70 eV heated from 260°C to 260°C but generally the enhancement of band gap energy occurred at the previous temperatures (Table 1 and Table 2). The magnitude enhancement of band gap energy indicates that the waste plastic polyethylene has potential to be applied into dye of solar cell.

The absorbance spectra and band gap energy are two basic from many other parameters to determine the appropriate material to be used as dye of solar cell. Recycled waste plastic polyethylene is accomplished photon absorber used in solar cell. It has absorption spectra at wavelength of 350-550 nm which means it has capability to absorb photons and produce electrons. Within solar cell, these electrons then injected into semiconductor materials and they flow throughout transparent conductive oxide (TCO) to the external circuit and to the counter electrode. The absorption of photons—by absorber material—becomes the key to run those processes in producing electrical energy. Furthermore recycled waste plastic polyethylene has also larger of band gap energy. It shows that recycled waste plastic polyethylene is quite capable to provide enough possibilities for semiconductor to accept electrons by large spectra of sunlight. Thus, recycled waste plastic polyethylene has huge potential to be applied as dye within solar cell.

4. Conclusion
Recycled waste plastic polyethylene has a spectrum absorption in the ~ 340-550 nm wavelength range which indicates it’s capability to be used as photon absorber of solar cell device. Furthermore the higher temperature affected the enhancement of the band gap energy of waste plastic polyethylene. It shows that recycled waste plastic polyethylene has a huge potential to be absorber materials for solar cell.
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