Effect of Band Gap of Biopolymer based Composites

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Abstract

The natural biopolymers are very eco-friendly as they are renewable and biodegradable in nature. Like conventional semiconductors and metals, conducting polymers have excellent electrical and electrochemical properties, they have inward much awareness in both fundamental and practical studies. The electrical conductivity of bio-polymer is increased by several methods. Egg films are easily formed by thermal treatment of egg white protein solutions. Mixing of proteins with oils, acids, metals, oxides enhance the maximum conductivity. Lanthanum and strontium nitrates are the mostly used as semiconductors by various researchers, hence in this experiment they are acted as dopants. This project aims to increase the electrical conductivity of egg white which is enriching with proteins. The specimens are prepared by dopants with different ratio that are strongly blended with egg white. The four specimens such as S_1,S_2,S_3 and S_4 egg incorporated with lactic acid, lanthanum nitrate and strontium nitrate are prepared by blending and heating process. The band gap energy of the specimens are characterized by UV-visible method. From the characterization, the band gap energy was calculated by Tauc's method. The electrical conductivity of the samples is compared before and after treatment of dopants. The results almost demonstrate an increase in conductivity after the incorporation of lanthanum nitrate, lactic acid, strontium nitrate by blending process.

Keywords: *egg albumin, lanthanum nitrate, stronium nitrate, band gap, blending process*

Introduction

Throughout history, humans have relied extensively on biological materials like wool, leather, silk, and cellulose. Today, such natural polymers can be tailored to meet specific needs[1]. The advent of modern biotechnologies fundamentally transformed the way that scientists view organisms and the materials they produce. Polymers play a central role both in the natural world and in modern industrial economies[2]. Some natural polymers, such as nucleic acids and proteins, carry and manipulate essential biological information, while other polymers such as the polysaccharides—nature's family of sugars-provide fuel for cell activity and serve as structural elements in living systems[3]. With advances in chemistry and materials science, a vast array of novel synthetic polymers has been introduced over the past century[4].As a typical example, a rich spectrum of conductivities has been achieved, ranging from insulating to metallic[5, 6]. It is reported that the electrical and optical properties of polymers can be improved to a desired value by integrating appropriate dopant materials [7, 8].

This project endeavours to boost the electrical conductivity of egg white which is elevating in proteins. The specimens are synthesised by dopants with various ratio have sturdily blended with egg white. The four specimens such as S_1, S_2, S_3 and S_4 egg built-in with lactic acid, lanthanum nitrate and strontium nitrate were synthesised by blending and heating process. The band gap energy of the specimens is characterized by UV-visible method. From the characterization, the band gap energy was calculated by Tauc's method [9]. The electrical conductivity of the samples is compared before and after treatment of dopants.

Methods and Materials

The specimens were prepared from high purity Lanthanum nitrate (99.9 %, Sigma-Aldrich), Strontium nitrate (99.9 %, Sigma-Aldrich), Lactic acid (99.9%, Sigma – Aldrich), Pure egg white albumin [99.9%]. The stoichiometric ratio of the materials such as Lanthanum nitrate and Strontium nitrate were measured and grounded. Both the Lanthanum nitrate and Strontium nitrate required for this study cannot be used intuitively, so the samples are grinded into thin particles. The thin particles mixed with lactic acid and then the grinded paste strongly blended with egg white constantly for 30 minutes to 40 minutes. After that the semi-liquid solutions were cast into various clean and dry petri dish. The samples were allowed to evaporated at hot air oven vacuum champers for 6 to 7 hours continuously until solvent- free films were formed. The samples were prepared in (1:1) ratio form. The specimen S_1 is denoted as 20 ml of pure egg white. The specimen S_2 is denoted as 20ml of pure egg white, 2ml of lactic acid, 0.2ml of lanthanum nitrate, 0.2ml of strontium nitrate. The specimen S_3 is denoted as 20ml of pure egg white, 2ml of lactic acid, 0.5ml of lanthanum nitrate. The specimen S_4 is denoted as 20ml of pure egg white, 2ml of lactic acid and 0.5 ml of strontium nitrate.

The samples were characterized by UV-visible absorbance mode within the wavelength range of 200 nm-800 nm. This type of measurements was used to determine the energy band gap using Tauc's method,

$$\alpha h\nu = B(h\nu - E_g)^n$$

$$\mathbf{E_g = (\alpha h\nu)^2 — h\nu}$$

The constant value of n is equal to ½ for direct allowed and forbidden transitions. The constant n also takes the value of 2 for the cases of indirect allowed and forbidden transitions respectively.

$\alpha \rightarrow$ absorption coefficient

$h\nu \rightarrow$ the photon energy.

$E_g \rightarrow$ the band gap energy of the samples

The energy gap of the various samples has been measured by using the above formula. As the band gap energy decreases the electrical conductivity increases. Eventually the electrical conductivity of the egg white is compared to the other three blended specimens.

Results and Discussion

In this study four specimens are synthesised namely S_1, S_2, S_3, and S_4respectively for pure egg white, egg white mixing with Lanthanum nitrate, strontium nitrate and lactic acid, egg white mixing with Lanthanum nitrate & Lactic acid and egg white mixing with Strontium nitrate & Lactic acid. The band gap energy value of the synthesized specimen has been characterized by using UV – vis absorption spectra.The UV-vis absorption spectra of the specimens S_1, S_2, S_3, and S_4 has shown in figures 1,2,3 and 4 respectively. The figure shows the plots of $(\alpha h\nu)^2$ versus hv (eV). From the figures, band gap energy can be obtained and the dominant type of electrical conductivity to be identified.

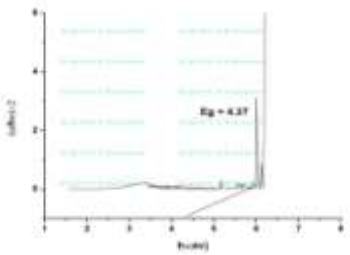

Figure 1 Determination of band gap energy for S_1

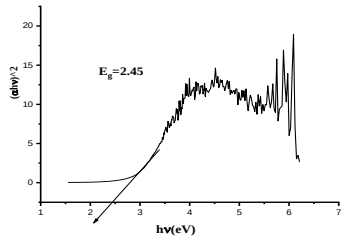

Figure 2 Determination of band gap energy for S_2

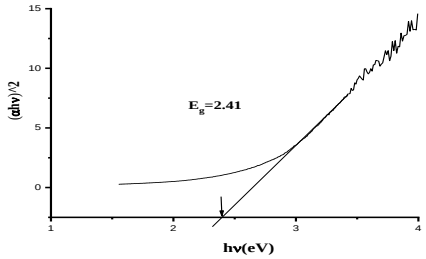

Figure 3 Determination of band gap energy for S_3

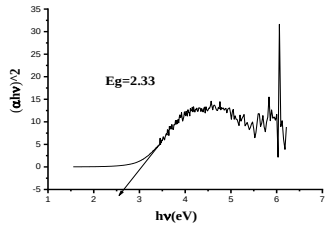

Figure 4 Determination of band gap energy for S_4

The band gap values estimated for all the specimens as summarized in Table [1].

Table 1 Band Gap Energy Values of Synthesized Specimen

S. No	Name of the specimen	E_g(eV)
1.	S_1(20ml of egg)	4.37
2.	S_2(20ml of egg+0.2ml of lanthanum nitrate+0.2ml of strontium nitrate+2ml of lactic acid)	2.45
3.	S_3 (20ml of egg+2ml of lanthanum nitrate+0.5ml of lactic acid)	2.41
4.	S_4 (20ml of egg+2ml of strontium nitrate+0.5ml of lactic acid)	2.33

The band gap energy of synthesized specimens is measured, and the values are 4.37, 2.45, 2.41 and 2.33ev respectively for S_1, S_2, S_3 and S_4 as shown in Table [1]. It is clear that, the band gap energy has decreased from specimen S_1 to S_4. As the band gapenergy decreases there is an increase in the conductivity of the specimen. As per the property of transition metal, the specimen S_4 has the highest conductivity. Specimen S_1 is an insulator and it has lowest conductivity since it has highest bang gap energy. The specimen S_2, S_3 and S_4 have lowest band gap energy compared with S_1. Transition metals such as Strontium nitrate in the periodic table belongs to group IIA are good conductors of heat and electricity [12]. A rare earth alkaline metal such as Lanthanum nitrate (S1) is found in the group III of the periodic table and has high electrical conductivity, but it is a heat resistive material [13]. Lactic acid is high heat resistive upto 70 degree Celsius, after that it slowly becomes a conductor [13]. Egg is a very bad conductor but it is conductive when it undergoes thermal vibrations [10]. Since when egg white is blended with Lanthanum nitrate (rare earth alkaline metal) and strontium nitrate (transition metal), it becomes semiconductor [13].

The conductivity is high for egg with Strontium nitrate than the egg with Lanthanum nitrate because Strontium nitrate is good conductor of heat but Lanthanum nitrate is a heat resistive material compared with Strontium nitrate. Under thermal vibrations, egg and Strontium nitrate blend has high conductivity, Lanthanum nitrate is heat resistance but egg is good conductor of heat [11]. When it is treated together under some temperature, Lanthanum resist the heat as it has low conductivity than Strontium [13].

Lanthanum nitrate, strontium nitrate are the metals and semiconductors as well. While, doping of strontium nitrate and lanthanum nitrate with egg under temperature of 70^0C to 80^0C for 6 to 7 hours, they become a semiconducting material. When compared with all the synthesized specimens, specimen S_4 [$20C_{37}H_{70}NaO_8P$:$2C_3H_6O_3$:$0.2Sr(NO_3)_3$] has the highest electrical conductivity.

Conclusions

The four specimens such as S_1,S_2,S_3 and S_4egg incorporated with lactic acid, lanthanum nitrate and strontium nitrate were prepared by blending and heating process. The band gap energy of the specimens have characterized by UV-visible method. From the

characterization, the band gap energy was calculated by Tauc's method. The band gap energy results that specimen S_1 (egg) has the highest band gap energy while for other three specimens S_2,S_3, S_4, the band gap energy decreased. The specimen S_1 is a pure egg white which is an insulator. When pure egg white is incorporated with transition metals (strontium nitrate) with lactic acid S_4, rare earth alkaline metal (lanthanum nitrate) with lactic acid S_3 and rare earth metal, alkaline earth metal, lactic acid S_2 the pure egg white became a conductor. Amongst all the specimens, S_4 (egg with strontium nitrate and lactic acid) has the highest electrical conductivity than the specimens S_2, S_3 and S_4. As the band gap energy decreased the electrical conductivity increased, the results suggest that the most spectacular correlation is that the higher electrical conductivity lower the band gap energy

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