Investigation of Arabic gum optical properties as UV-Blue light down conversion for light emitting diode application

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Abstract: LED’s as energy-efficient lighting is the best way to reduce the cost besides give good brightness. The use of Arabic gum as a remote phosphor for light down conversion. In this study, two experiments were conducted using Gum Arabic Malaysia and Gum Arabic Sudan in several annealing temperature (150°C and 200°C ) and different time 20, 40, 60, 80 and 100 minutes and using different mass, 100mg and 150mg. the gum power encapsulated in 0.7ml silicone gel and dried to do remote phosphor using for light conversion. The Gum Arabic from Sudan and Malaysia were measured using HPC-2 light source colorimeter. The measured result show that the gum Arabic has high value in rendering index, CRI (colour rendering index) if the gum annealed at longer time and at the optimal temperature. The CCT (correlated colour temperature) value that show the best result or positive values are below 2500. The gum Arabic with melting process also show improvement in result. The mass of the powder used give high concentration thus the CRI value is nearest to the 80 as references value.

1. Introduction

Gum Arabic (Gum Arabic Malaysia and Gum Arabic Sudan) is an Secretions collected principally from the Acacia Seyal and Acacia Senegal trees that is rich in soluble fiber non-viscous [1,2]. Age of ripening of the tree must be five years or more for gum production to occur. Therefore, the gummosis is in direct competition with growth of tree. The gummy substance dries on the branches to form hard nodes which are selected from the tree [3,4].A thousand species of Acacia trees or more but just two types of them use to significant for commercial purpose [4]. The produces the best type of gum and provides the bulk for world trade is Acacia Senegal (L) and the produces a lower grade of gum is Acacia Seyal. The gum from Acacia Senegal (L) is considered as the best in quality and widely used species of natural plant gums because it contains low quantities of tannins [5]. Gum Arabic has a very complex structure, which is highly heterogeneous complex polysaccharide containing D-galactose (~49%), L-arabinose (~27%), L-rhamnose (~13%), Dglucuronic acid (~14.5%), 4-0-methylglucuronic acid (~15%), as a smaller fraction of nitrogenous substances and the major constituents [3]. The carbohydrate composition can vary depending on the age of the tree, site of tapping, the location and from season to season. The structure of Arabic's gum are three components which the major component is arabinogalactan-peptide (AG) fraction (90%) followed by arabinogalactan-protein (AGP) fraction (<10%) and glycoprotein (GP) fraction (<1%) [6]. The major component is a highly branched polysaccharide consisting of β-galactose
backbone related through branches of rhamnose and arabinose which the arabinogalactan-protein complex (GAGP-GA glycoprotein) which arabinogalactan chains which covalently related to a protein chain through serine and hydroxyproline group [6]. The smallest of fraction possesses is the higher protein contents and a glycoprotein. By pronate enzyme can be degraded A high molecular mass fraction of the gum [3]. When compared with other gums, Gum Arabic high water solubility and a relatively low viscosity. The water is its main solvent for the gum but insoluble in organic solvents such as alcohol. Therefore, the main solvent is cheap, readily available and non-chemically based and can get dissolved in water in a concentration of 50% w/v, forming a versatile in application [7]. Less than 10% of gum's solutions have a low viscosity and respond to Newtonian behaviour [8]. The gum has one of the major function characteristics to ability to acts as an emulsifier for essential oils and flavours [8]. It is attractive as magnetite nanoparticles coating because of its hydrocolloid emulsifier, stabilizer and biocompatibility properties [9]. When heating of Gum Arabic solution for long time get causes proteinaceous components to precipitate out of solution, there by influencing the gum’s emulsification. Acacia Senegal is very effective emulsifying and stabilising agent.

Gum Arabic is most important commercial polysaccharide and is probably the oldest food hydrocolloid in current use [9]. According to article written by Mohamed A. Siddig [10], when increase with frequency found the conductivity while opposite behaviour observed for the dielectric. Also the increase concentration was found increase the absorption. Gum Arabic is an efficient encapsulating material because of its low viscosity in aqueous solutions and high solubility as comparison with another hydrocolloid gums. In addition, this wall material fulfils the roles of both a drying and a surface-active agent matrix [11-13]. Due to their rapidly improving efficiency of Light emitting diodes (LEDs) are on the verge of a breakthrough in general lighting. On this time, by one or more phosphor materials use in white LEDs with high colour rendering are mainly based on wavelength conversion [14]. The low cost manufacturing and the uses of white light sources is one of offer significant advantages of OLEDs. The emission wavelength of the inorganic structure from An absorption band aligned is coming processing of a hybrid inorganic/organic LED architecture where a blue emissive inorganic LED is coated with an organic material. The inorganic LED with The organic material acts as an energy down-converter changing some of the emitted high energy blue luminescence to lower energy yellow-red light that when combined delivers a high quality white output. One of the inorganic LED is the III-nitride which choosing for the material system to alloy any system which can emit light from the ultraviolet (UV) through the visible to infrared spectrum [15]. Hybrid inorganic/organic LEDs with the down-conversion layer can get good producer and quality light emission from cool to warm white. Directly, the organic material with absorber band can coming nearly align with the inorganic LED with emission band to use such as an efficient energy down-converter for white light generation. Several of the photons go out from the blue LED excites the combination of the two creates white light and the organic material producing yellow light [16].

2. Experimental procedure

The procedure of the experiment details on how the sample is prepared and what are the full precautions steps that should be followed. This experiment was using Silicone to encapsulate the Gum Arabic (Malaysia – Sudan) before and after annealing and test it by UV-Blue light. Gum Arabic must be dried gummy and are cleaned to remove any contamination that could affect our experiment result. The two types of gum Arabic were directly used to make the powder gum Arabic. The gums were grinded using mill blender. Then, the powders were sieved using fine cloth filter to remove any course particles or impurities. The storage of the gum powder must away from the windy environment and stored in air-tight container to avoid the gum becomes sticky due to the presence of moisture in the air.

The gums are weighted 1 g each for 20, 40, 60, 80 and 100 mins annealing period. The oven was heat up for 30 minutes early. The gums powders were put into glass petri dish and evenly. After 20 mins the powder is taken out and cooled for 5 mins before stored in a small bottle. The silicone mixture has two types which is A and B where the ratio is 1:1. The mixture of silicone liquid is mixed well and
continuously stirred to prevent clump. All the powders were added into the silicone mixture evenly using electric hand stirrer. The mixture is then let dry on the mould rack for one day or dry in the oven for 20 mins at 100°C. The samples then was stored in sealed plastic to prevent dust particles stick on them. HPC-2 Lightsource Colorimeter from China Company, Hopoo Optoelectronic Technology Co.Ltd is used in the measurement of colour correlativel temperature (CCT), colour rendering index (CRI) and CIE values of the gum Arabic from Sudan and Malaysia. This tool is to observe the brightness of the samples can give. All the procedure shown in Figure 1.

Figure 1. Experimental procedure.
3. Results and Discussion

3.1 Structural Characterization (X-ray Diffraction)

Basically, XRD (X-ray Diffraction) is a non-destructive technique using identify crystalline phases and orientation of the materials. In this study, we used XRD for analysing the structural properties of Arabic gum before and after undergone annealing process. This technique also can measure the average spacings between layers of the atom. The results of XRD will show peak positions, peak intensities, peak width and shape of the peaks. By using Debye-Scherrer formula, the average crystalline crystallite size:

\[
D = \frac{0.94 \lambda}{\beta \cos \theta}
\]  

Where

- \( D \) = crystalline size of the material
- \( \lambda \) = wavelength of X-ray used (1.54 Å)
- \( \beta \) = the broadening of diffraction line measured at half its maximum intensity in radians
- \( \theta \) = the angle of diffraction

**Figure 2.** XRD pattern of a) raw gum Arabic Malaysia b) gum Arabic Malaysia annealed at 200°C for 80 minutes c) gum Arabic Malaysia annealed at 150°C for 100 minutes.

**Table 1.** X-Ray results for a) raw gum Arabic Malaysia b) gum Arabic Malaysia annealed at 200°C for 80 minutes c) gum Arabic Malaysia annealed at 150°C for 100 minutes.

| Position (*°2Th*) | Height (cts) | FWM (*°2Th*) | d-spacing (Å) | Real Intensity (%) | Tip width (*°2Th*) | Grain size, D (mm) |
|-------------------|--------------|--------------|--------------|-------------------|-------------------|------------------|
| 22.4425           | 25.38        | 0.9840       | 3.9616       | 20.52             | 1.1808            | 8.1729           |
| 21.6328           | 57.80        | 0.2116       | 4.0624       | 83.65             | 0.2540            | 34.7245          |
| 21.6328           | 33.37        | 1.4941       | 4.1081       | 100.00            | 1.7929            | 5.3826           |
Figure 3. XRD pattern of a) raw gum Arabic Sudan b) gum Arabic Sudan annealed at 200°C for 40 minutes c) gum Arabic Sudan annealed at 150°C for 100 minutes.

Table 2. X-Ray results for a) raw gum Arabic Sudan b) gum Arabic Sudan annealed at 200°C for 40 minutes c) gum Arabic Sudan annealed at 150°C for 100 minutes.

| Position (°2θ) | Height (cts) | FWHM (°2θ) | d-spacing (Å) | Real Intensity (%) | Tip width (°2θ) | Grain size, D (mm) |
|---------------|--------------|------------|---------------|-------------------|----------------|-------------------|
| 22.1480       | 41.31        | 0.1792     | 4.0137        | 100.00            | 0.2151         | 44.8783           |
| 22.1166       | 23.45        | 0.7872     | 4.0193        | 61.32             | 0.9446         | 10.2162           |
| 21.4964       | 35.62        | 1.2749     | 4.1338        | 95.39             | 1.5298         | 6.3081            |

3.2. Optical characterization

3.2.1. UV-Vis Absorption for Gum Arabic Malaysia and Gum Arabic from Sudan.
UV-Vis optical absorption spectra of the samples of Gum Arabic with different concentration are stated as shown below. The maximum peak in Gum Arabic Malaysia was found to shift at higher value with increasing concentration. This is concluded that the peak is proportional to the concentration. We can see the absorption increase with concentration of Gum Arabic Malaysia. The absorption spectrum of sample in Figure 4 (1,3) with mass 100mg exhibits maximum absorption at wavelength 277 nm, while the maximum absorption with mass 150mg exhibits at wavelength 220 nm.

The absorption spectrum of gum Arabic Sudan, with mass 100mg exhibits fluctuate peaks. But the maximum absorption occurs at 293 nm. For gum Arabic Sudan with mass 150mg the maximum peak at 285 nm as shown in Figure 4 (2,4).

3.2.2. Light emission from Gum Arabic Malaysia and Gum Arabic from Sudan.
For Gum Arabic Malaysia the best result with the highest rendering index with mass 100mg. This sample was annealed at 200°C by blue furnace within 20 minutes. The result shows that the mass also play the role in rendering index result because the concentration of the sample increase thus the absorption of the UV high. The value for rendering index, CRI is 77.6 meanwhile the correlative colour temperature, CCT is 5415.
Figure 4. a) Gum Arabic Malaysia absorption annealed at 200°C within 20 minutes with mass 100mg. b) Gum Arabic Sudan absorption annealed at 200°C within 40 minutes with mass 100mg. c) Gum Arabic Malaysia absorption annealed at 200°C within 80 minutes with mass 150mg. d) Gum Arabic Sudan absorption annealed at 200°C within 80 minutes with mass 150mg.

Gum Arabic Malaysia sample with mass 150mg shows rendering index, CRI 75.7 lower than previous sample with 100mg. The correlative colour temperature is 3378. The sample with mass 100mg gum Arabic powder shows more effective for white light conversion compared to the mass of 150mg with temperature 200°C. as shown in Figure 5 and Table 3.

For Arabic Gum Sudan the result shows that the mass also play the role in rendering index result because the concentration of the sample increase thus the absorption of the UV high. The mass of gum Arabic powder for encapsulate with the silicone liquid is 150mg and the annealing temperature was 200°C within 40 minutes is the optimal result for white light conversion. The result shows that the mass also play the role in rendering index result because the concentration of the sample increase thus the absorption of the UV high. The CCT value is 4525. The mass of 100mg gum Arabic powder shows less effective for white light conversion compared to the mass of 150mg with temperature 200°C. The annealing temperature at 200°C is more effective for white light conversion than temperature at 150°C. The shown in Figure 6 and Table 4.
Figure 5. Characteristic of the white light emitted from Gum Arabic Malaysia Sample at temperature 200°C.

Table 3. The colorimeter results for Gum Arabic Malaysia.

| Sample          | GAM       | Sample          | GAM       |
|-----------------|-----------|-----------------|-----------|
| Annealing time (min) | 20        | Annealing time (min) | 80        |
| CCT(K)          | 5415      | CCT(K)          | 3378      |
| CIE(X)          | 0.3325    | CIE(X)          | 0.4082    |
| CIE(Y)          | 0.3064    | CIE(Y)          | 0.3834    |
| CRI             | 77.6      | CRI             | 75.7      |
| Mass (mg)       | 100       | Mass (mg)       | 150       |
| Silicon (mL)    | 0.7       | Silicon (mL)    | 0.7       |
Figure 6. Characteristic of the white light emitted from Gum Arabic Sudan Sample at temperature 200°C.

Table 4. The colorimeter results for Gum Arabic Sudan.

| Sample          | GAM |
|-----------------|-----|
| Annealing time (min) | 40  |
| CCT(K)          | 8483|
| CIE(X)          | 0.2997|
| CIE(Y)          | 0.2772|
| CRI             | 76.5 |
| Mass (mg)       | 100 |
| Silicon (mL)    | 0.7 |

4. Conclusion
From the result, we conclude that the structural properties the different type of Gum Arabic and method used to do encapsulated sample give different characterization. The longer time annealing at higher temperature affect the Gum Arabic conversion to the UV Blue Light. This shows that Gum Arabic properties in nanoparticles do involve in conversion of UV Blue Light to white light. From all results, we conclude that encapsulated Gum Arabic Malaysia is good in conversion than Gum Arabic Sudan. It's shown in standard colour range with the best CIE and CRI. The quality of the White Light Emitting Diode (WLED) is improved by using the different mass and time taken for annealing process.

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