Study of Colorimetric properties of Ethidium bromide dye-doped PVP/DNA film.

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Abstract: The effects of deoxyribonucleic acid (biological polymer DNA) on full brightness, and color matching functions of Ethidium bromide dye doped PVP/DNA films were studied. Ethidium bromide dye doped PVP/DNA films were deposited on soda-lime glass substrates by the deep casting method. The variation of CIE chromaticity coordinates for PVP/DNA films with increasing Ethidium bromide dye concentration values are determined. The CIE 1931 color space move to the magenta region. The results indicate that Ethidium bromide dye doped PVP/DNA films have potential promising material for optical device applications and candidates used for LEDs pumped by UV chips and applied in many advanced technologies.

Keywords: deoxyribonucleic acid; CIE 1931 color space; Ethidium bromide; CIE chromaticity; PVP

1. INTRODUCTION

It was essential to find new nonlinear optical materials with a high optics nonlinear coefficient for potential novel opto-electronics applications [1]. Nonlinear refraction [2] and nonlinear absorption [3] are the essential third-order nonlinear optical parameters of Ethidium bromide or Nano-composite films for optoelectronic [4], photonic devices [5], limiter devices [6], all optical switching[7,8], thermal lens [9-11], dosimetry [12-14], shielding [15,16], nuclear detector[17] and labeling of biological molecules [18]. All this requires searching for materials that exhibit nonlinear properties, such as organic dye[19,20], azo dye [21,22], Schiff-base dye [23], organic compound [24], conducting polymer [25], polymer film [26-28], polymer solution[29], biopolymer [30,31], nanoparticle [32], Nanocompouse [33,34] and liquid crystal [35]. In recent decades, various technologies of optical limiters have been affected by the widely used applications of laser technology [36]. To overcome this worsening of laser blindness, many countries around the world are making efforts to develop new materials with a good optically limiting character. [37,38]. Usually, transparent polymeric materials are preferred over the rest of the traditional optical materials (crystals and glass) because of the possibility of adding to them many impurities such as dyes [39-41], which leads to a change in the properties of the polymer [42]. The polymethylmethacrylate (PMMA) or DNA polymer is one of the most used host polymers due to its high transparency within the visible spectrum and its resistance to optical damage from laser radiation [43-45]. Many researchers have studied the properties of this polymer when
denatured with different materials [46-53]. In general, the properties of substances in the solid media can be explained based on their crystal structure and the force of attraction between their atoms, and the optical and electrical properties of solids media (polymer films or metals) depend on the distribution of electrons in their atoms and thus depend on the method of paving and paving of atoms [54-57]. The use of this polymer helps to stabilize the color of the sample, maintain its brightness and not change its color over time, which makes it easy and useful for use in contemporary technology applications.

In this work, we presented our studies of the CIE 1931 color space model of polyvinyl pyridine (PVP)/deoxyribonucleic acid (biological polymer DNA) with various Ethidium bromide (EtBr) dye concentrations which were prepared by a deep casting method, doped in PVA/DNA polymer. The color fastness of the samples 2wt% EtBrPVP + DNA were measured by CIE chromaticity theoretical model. To our knowledge, there is no report published before on the study of the Colorimetric properties of Ethidium bromide dye-doped PVP/DNA film.

2. CIE 1931 COLOR SPACE
The CIE 1931 XYZ color space (also known as the CIE 1931 color space) was one of the earliest mathematical definitions of color sense and was developed by the International Lighting Corporation in 1931 [58,59]. This system is an RGB system defined since 1931, and it uses three primary colors: red R, green G, and blue B. It is based on a basic theory that mixing the three components is equivalent to a white color, which it counts as a color reference, which has become the source of equal energy, and this is due to the representation the CIE XYZ color space was derived from a set of experiments performed by David Wright [60] and John Guild [61] in 1920. Their experimental results were grouped into a specification of the CIE RGB color space from which the CIE XYZ color space was derived.

3. TRIPLE STIMULUS VALUES
There are two types of optic cells in the human retina which are rods and cones. Rods are responsible for seeing in night light conditions, while cones are responsible for seeing in good lighting conditions. In turn, the cone cells are divided into three types of receptors that are sensitive to short (S), medium (M) and long (L) wavelengths. Thus, there are three variables describing sensitivity to color. Chromatogram values are defined by the amounts of three primary colors in three compounds of the colourful system. The values of triple stimulation in the CIE 1931 color space are denoted by X, Y, Z [62,63]. Any special method of linking the triple stimulation values with each color is called (colour space) and the 1931 color space CIE is distinctive because it depends on direct measurements of human visual perception, and it is useful as a rule, other colour spaces are known for them. Since the human eye has three kinds of color sensors that meet various wavelength ranges. Figure 1 shows a color scheme for the CIE 1931 color space, which shows a complete description of all visible colors with a three-dimensional drawing. However, the notion of colour may be split into two parts: chromatic brightness. For example, white is a bright color, while Gray is a lesser white version. In other words, the colors white and grey are the same while their brightness is different. Design the XYZ color space so that the variable Y is a measure of color brightness. The chromaticity of a color is determined by two derivative variables x and y, which are two of the three normalized values that are the functions of the triple stimulus values X, Y, and Z.
4. THEORETICAL MODEL

The triple stimulation values in the CIE XYZ color space are not the response of the eye to the S, M, and L wavelengths, but rather the triple stimulation values called X, Y, and Z that can be roughly red, green and blue. (Note that the values of X, Y, and Z are not physically seen as red, green, and blue colors. Rather, they are counted as variables derived from the colors red, green, and blue). Due to the nature of the cones’ distribution in the retina, triple stimulation values depend on the field of view of the observer. To bypass this changing hurdle, the International Lighting Authority defined a Standard observer. The colorimetric response of the average human vision was modified by a field of view at an angle 2°, due to the common belief that the sensitivity of the color cones lies within an arc (two degrees) of the fovea of the retina. That is why the CIE 1931 standard observer is known as the CIE 1931 2° standard observer. The CIE 1964 10° was developed as a substitute for the previous observer, which is newer but less frequently used and has drawn from the works of Stiles, Burch [65] and Speranskaya [66]. The derivation of the CIE 1931 equations is based on the description of the color space in RGB where the color matching equation is given by the following relationship [67]:

\[ Q = RR + GG + BB \]  \hspace{1cm} (1)

Since R, G, B is the unit amounts of the triple catalysis and Q is the unit amount of the test stimul It is appropriate to depict the two-dimensional plane of color effects, which are illustrated by the color scheme, which we can express in the following relationship:

\[ r' + g' + b' = 1 \]  \hspace{1cm} Where:

\[ r' = \frac{R}{R + G + B} \]  \hspace{1cm} (2)

\[ b' = \frac{B}{R + G + B} \]  \hspace{1cm} (3)
and \( g(\lambda) \) represent a set of CMF color matching functions, so the CIE \( b(\lambda) \cdot r(\lambda) \) Suppose that 1931 standard observer can be described as a CMF set as follows:

\[
R(\lambda) = r(\lambda)Q(\lambda) \\
G(\lambda) = g(\lambda)Q(\lambda) \\
B(\lambda) = b(\lambda)Q(\lambda)
\]

when we applied the set equations 1-7 to the color matching functions (CMF), the color coordinates of the space of the stimuli that give monochromatic are written as follows [68]:

\[
r(\lambda) = \frac{r(\lambda)}{r(\lambda) + g(\lambda) + b(\lambda)} \\
g(\lambda) = \frac{g(\lambda)}{r(\lambda) + g(\lambda) + b(\lambda)} \\
b(\lambda) = \frac{b(\lambda)}{r(\lambda) + g(\lambda) + b(\lambda)}
\]

Suppose that \( Q(\lambda) \) is the spectral power distribution function of the stimuli \( Q \) which given by the three stimuli in terms of the CIE XYZ standard observer with the following relationships:

\[
X = K \sum_{\lambda=\lambda_{\text{min}}}^{\lambda_{\text{max}}} \frac{\lambda_{\text{max}}}{Q(\lambda)\bar{x}(\lambda)\Delta\lambda} \\
Y = K \sum_{\lambda=\lambda_{\text{min}}}^{\lambda_{\text{max}}} \frac{\lambda_{\text{max}}}{Q(\lambda)\bar{y}(\lambda)\Delta\lambda} \\
Z = K \sum_{\lambda=\lambda_{\text{min}}}^{\lambda_{\text{max}}} \frac{\lambda_{\text{max}}}{Q(\lambda)\bar{z}(\lambda)\Delta\lambda}
\]

Whereas, \( \bar{x}(\lambda) \), \( \bar{y}(\lambda) \) and \( \bar{z}(\lambda) \) are CIE 1931 standardized colorimetric observation which can be thought of as the spectral sensitivity curves of the three photoreceptors that give the triple stimulation values of X, Y, and Z. Where \( \lambda_{\text{min}} \) and \( \lambda_{\text{max}} \) are the minimum and the maximum value of the monochromatic light wavelength measured in nanometers, and K is the arbitrary calibration factor which is usually equal to 631 m/W and Y value is given in units of candles per square meter (cd/m²).

5. MEASUREMENTS AND RESULTS
We applied this theoretical model to the Ethidium bromide (EtBr) dye doped biological polymer films and the method was prepared as follows: For prepared polymer films, high purity chemicals (Merc, > 99% purity) such as Ethidium bromide dye and polymer polyvinyl pyridine (PVP) and deoxyribonucleic acid (biological polymer DNA) were used as precursors. The appropriate amount of Ethidium bromide dye and polyvinyl pyridine (PVP) were dissolved in water one by one at 20 mints intervals. The temperature of the sol was gradually raised to 50 °C and kept for 3h to get the gel. The PVP gel has good adhesive properties and the ability to hybridization the function of molecules. Among these good features, we choose EtBr dye doped 2wt%PVP + DNA system to obtain a low intersystem crossing rate \([69]\). All samples examined for this study were deposited on soda-lime glass substrates through a deep casting at ambient temperature. Before deep casting, the glass substrate was first degreased by a good detergent, rinsed thoroughly with distilled water and then boiling water. To eliminate macroscopic contamination, the substrates were ultrasonically cleaned in an ethanol blend, methanol and acetone (each of 30% in volume) for 7 min. The latter procedure was repeated in distilled water. Finally, all substrates were immersed in ethanol, rinsed with distilled water and dried with nitrogen. This method has been applied to 0.5 mm Ethidium bromide dye concentration film to measure the triple stimulation values from the CIE 1931 color space. The polymer film in this way is called 2wt% EtBrPVP + DNA film. The same procedure was repeated to remaining Ethidium bromide dye concentrations, namely, 2, 4 and 6 mm.

**FIGURE 2.** CIE 1931 color space of 2wt% EtBrPVP + DNA at 0.5mM.
FIGURE 3. CIE 1931 color space of 2wt% EtBrPVP + DNA at 2mM

FIGURE 4. CIE 1931 color space of 2wt% EtBrPVP + DNA at 4mM
FIGURE 5. CIE 1931 color space of 2wt% EtBrPVP + DNA at 6 mM

Figs. 2-5 shows the room temperature colorimetry properties of Ethidium bromide dye-doped polymer polyvinyl pyridine (PVP) and biological polymer (DNA) were investigated using CIE 1931 standardized colorimetric method and the color space data are given in Table 1. The colorimetry sample showed high resistivity to change samples color or change color matching functions and as a result, reliable triple stimulation values in the CIE1931 color space measurement could be performed. This is obviously related to the good smooth of the polymer samples.

| TABLE 1. Triple stimulation values with different 2wt% EtBrPVP + DNA concentration. |
|---------------------------------|-------|-------|-------|
| Con. Mm | X (red) | Y (green) | Z (blue) |
| 0.5     | 96.343  | 87.0684 | 93.6103 |
| 2       | 76.9093 | 58.0016 | 81.3477 |
| 4       | 74.7033 | 54.7959 | 78.141 |
| 6       | 72.1004 | 53.1931 | 76.5376 |

6. CONCLUSIONS
We conclude that polymer polyvinylpyrrolidone (PVP) is a good matrix for EtBr dye in its incorporation into the double helix of the DNA molecule and suitable stricture material for practical applications in optical devices. The material is color-preserving and the addition of the biological polymer according to its color capabilities, that is, gave the material stable color and a bright recipe and full brightness as shown in the figures. EtBr dye-doped polyvinylpyrrolidone (PVP) film very useful application and contributing to the manufacture of molecular electronic devices and Nano-robots, in the field of LCD consumer electronics and the manufacture of sensors. The results indicate that Ethidium bromide dye doped PVP/DNA films have potential promising material for optical device applications and candidates used for LEDs pumped by UV chips and applied in many advanced technologies.

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