

# Impact of the Emission Fluorescent Dyes Properties and Radiation heat transfer on Cotton Knitted Fabrics

Dr. Faten Ajeeb<sup>1</sup>, Mhd. Ghaith Burhani<sup>2</sup>, Alaa Khsara<sup>3</sup>

**Abstract**—Nowadays fluorescent dye is the one of the functional dyes sensitive by light, it absorbs energy from the light beam, and gives a clearly light in the very dark places. Functional dyes are very useful in various differentiated fields. Such as medical diagnostic, biochemical. Fluorescent dyes have also been used for the construction of lasers, photoelectric cells, and solar batteries. It also used in some kinds of innovation textile production. In this work fluorescent dyes are used for indicate the emission time of the printed cloth where the change in the time lighting and printed area, the emission time of the printed cloth increased in the biggest area and longest time. Identify through search that the radiation heat transfer of the fluorescent printed fabric surface increased about (15%) when the temperature increased about (12 K), and the decay time also increased, due to the increases of the absorbed energy. But in another hand, the fluorescent dye life time has been decreased with lighting time increased, the reduction can reach (0.6%) when the lighting time has increased (100%). These results can give a good properties for the cloth that is printed by fluorescent dyes as the final uses.

**Keywords**—fluorescent dyes, emission time, heat transfer, knitted fabrics.

## 1 Introduction

During the past 20 years there has been a remarkable Growth in the use of fluorescence in the biological sciences<sup>1</sup>. The sensitivity, simplicity, and selectivity of Fluorescence-based techniques make them particular attractive for in vitro and in vivo cellular and molecular biology studies<sup>[2]</sup>. Fluorescent dyes are used according to fashion trends in leisurewear clothes, especially sportswear and in the work clothes worn outside <sup>[5]</sup>. And the physical properties of dyed fabric are very much important to meet those functional purpose. Knit fabric is formed by the intermeshing of loops. TPI of yarn is comparatively lower than woven fabric. The knit fabric shows high amount of stretch and elasticity due to loop structure and dimensionally less stable than woven fabric. Air permeability is more due to voluminous structure of knitted fabric <sup>[12]</sup>. Jersey is a knit fabric used predominantly for clothing manufacture. In 1930's it has been experienced that certain dyes and resins combination produce brighter colors than normal colors and had the unique effect of "glowing" under ultra violet or black light.

discovered as 'fluo-rescine' <sup>[14]</sup>. Since this time, several dozen dyeing substances showing fluorescent ability have been recognized. Phosphorescent paints also emit light when excited by visible or ultraviolet light, but do so over extended periods. This long-lasting effect of phosphorescent also allows kids to enjoy "glow-in-the-dark" adhesive stars on the ceilings of their rooms <sup>[14]</sup>.

Recently, fluorescence imaging has become one of the most powerful techniques for monitoring biomolecules in living systems. Fluorescent sensors are essential molecular tools for bio imaging. [So far, a large number of fluorescent sensors have been constructed. However, most of them have the absorption and emission in the visible range (400–650 nm). By contrast, the fluorescent sensors with absorption and emission in the near-infrared (NIR) region (650–900 nm) are relatively few, although they are highly sought due to their useful applications in chemical biology] <sup>[4]</sup>.

This research discusses the emission properties of these dyes to find the best area when the clothes are printed by these dyes to give the main aim of these dyes which is let the clothes shine more and more time in the dark places especially for police suits, depending on the phenomena of fluoresces, the emission life time of the dyes, and the radiation heat transfer.

### 1.1 Phenomena of Fluoresces or luminesce

Luminescence is the emission of light from any substance, and occurs from electronically excited states. Luminescence is formally divided into two categories: fluorescence and phosphorescence; depending on the nature of the excited state. In excited singlet states, the

•Dr. Faten H. Ajeeb, lecturer in Biomedical Engineering Faculty – Andalus University – Tartus – Al Qadmus– Syria & in Biomedical Engineering Department - Damascus University – Faculty of Mechanical and Electrical Engineering - Damascus – Syria E-mail: [seba.f1999@gmail.com](mailto:seba.f1999@gmail.com).

•Mhd. Ghaith Gh. Burhani, engineer in Mechanical Power Engineering Department - Damascus University – Faculty of Mechanical and Electrical Engineering - Damascus – Syria.

•Alaa K. Khsara, Engineer in Textile Industries Mechanical Engineering and Techniques Department - Damascus University.

[Fluorescent dyes are considered to be those dyes which absorb and emit radiation in the visible spectral range. In 1971, Bayer designated the fluorescent dye he

electron in the excited orbital is paired (by opposite spin) to the second electron in the ground-state orbital. Consequently, return to the ground state is spin allowed and occurs rapidly by emission of a photon. The emission rates of fluorescence are typically  $10^8 \text{ S}^{-1}$ , so that a typical fluorescence lifetime is near 10 ns ( $10 \times 10^{-9} \text{ S}$ ). The lifetime ( $\tau$ ) of a fluorophore is the average time between its excitation and return to the ground state [1].

Phosphorescence is emission of light from triplet excited states, in which the electron in the excited orbital has the same spin orientation as the ground-state electron. [Transitions to the ground state are forbidden and the emission rates are slow ( $10^3$  to  $10^5 \text{ S}^{-1}$ ), so that phosphorescence lifetimes are typically milliseconds to seconds] [1,8].

Fluorescence typically occurs from aromatic molecules. Some typical fluorescent substances (fluorophores) are shown in Figure [1]. One widely encountered fluorophore is quinine, which is present in tonic water. If one observes a glass of tonic water that is exposed to sunlight, a faint blue glow is frequently visible at the surface. This glow is most apparent when the glass is observed at a right angle relative to the direction of the sunlight, and when the dielectric constant is decreased by adding less polar solvents like alcohols [1].

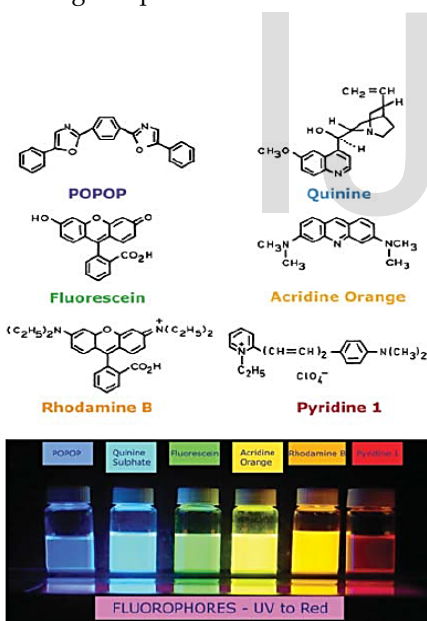


Fig.1. Structure of typical fluorescent substances

### 1.2 Fluorescence life times (emission time)

The lifetime of the fluorophore in the absence of non-radiative processes is called the intrinsic or natural lifetime, and is given by [1]:

$$\tau_n = \frac{1}{\Gamma} \quad (1)$$

The fluorescence lifetime is a measure of the time a fluorophore spends in the excited state before returning to the ground state by emitting a photon [7]. the lifetimes of fluorophores can range from picoseconds to hundreds of nanoseconds.

As shown in the intensity decay figure Figure 2. The fluorescence lifetime,  $\tau$  is the time at which the intensity has decayed to  $1/e$  of the original value. The decay of the intensity as a function of time is given by:

$$I(t) = \alpha e^{-t/\tau} \quad (2)$$

Where  $I(t)$  is the intensity at time  $t$ ,  $\alpha$  is a normalization term (the pre-exponential factor) and  $\Gamma$  is the lifetime. Knowledge of the excited state lifetime of a fluorophore is crucial for quantitative interpretations of numerous fluorescence measurements such as quenching, polarization and FRET.

Excited state lifetimes have traditionally been measured using the "time domain" method or the "frequency domain" method.

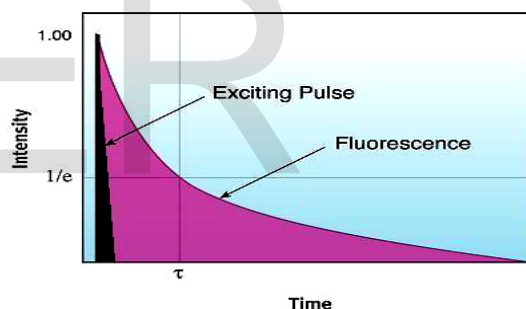


Fig. 2. Representation of the fluorescence decay following excitation with a short pulse

### 1.3 Heat Transfer

Heat transfer (or heat) is thermal energy in transit due to a spatial temperature difference. When a temperature difference exists across a boundary, the Second Law of Thermodynamics indicates the natural flow of energy is from the hotter body to the colder body. The Second Law of Thermodynamics denies the possibility of ever completely converting into work all the heat supplied to a system operating in a cycle [14].

This research, especially interested in radiation heat transfer, to find the impact of the heat on the emission properties of the dyes, to study the relationship between the fluorescent dyes emission and the temperature that the cloth has been raised to by the heat of the lighting. As known: [Thermal Radiation: Radiant heat transfer involves the transfer of heat by electromagnetic radiation that arises due to the temperature of a body] [15].

## 2 Methodology and Experiments

### 2.1 Materials

#### 2.1.1 Fluorescent dye Powder

The dye used is (JIN BAI DI) Bright UV Reactive Pigment Fluorescent Neon Powder, Fluorescent Powder Pigment Neon Use in resin Nail wax art PVA varnish paints Applications: In apparel printing, Cosmetic Material, advertising plates, safety signs, traffic, green and yellow colors are used.

#### 2.1.2 Binders

Binders used for printing were bricoprint binder SF20E, prepared PU New, thermistor (textile bath dyeing binder) It is a white paste containing a cross-linking polyacrylate, with mineral oil in water. It is a ready-for-use pigment print paste and contains thickener and other auxiliaries .

#### 2.1.3 Thickener

Was used in the formulation of pastes for printing chromazone slurries. It has a smooth, creamy consistency and is an inverse copolymer emulsion of ethylenically unsaturated monomers in hydrocarbons.

#### 2.1.4 Fabric

The fabric used for printing was (100%) Cotton, White, knitted structure (single jersey weft knit), density (0.37 g/cm<sup>3</sup>), porosity (0.87%), yarn count (30 Nm). Cotton was selected for experimental purposes due to its common usage in textiles and its natural origin, the basis weight 120 (g/m<sup>2</sup>), the thickness about 0.55 (mm). It can be used another kind of the raw materials.

### 2.2 Preparation of Printed Samples

The pigment paste has prepared by using the percentage (15% Fluorescent dye + 85% Emulsion thickener), another recipe can be used, and increase the amount of the dye to increase the influence of the fluorescent dye. The samples were printed by silk screen printer, in a factor.

### 2.3 Testing

#### 2.3.1 Fluorescent dye emission test (lighting time towards emission time)

This test is used to know what the emission time of the fluorescent dyes in the dark places until the decay of the light from each dye with different times of any light that is exposed the dye which printed on any kind of clothes. The experiences has done as the following method:

A printed sample with specific area has exposed about (15 cm<sup>2</sup>) by fluorescent dye to sunlight at a temperature (321 k). According to different times. Then the sample

was transferred to a dark place to see the emission time of the sample by changing of the time, and calculated the emission time of the sample until the decay of the light from the fluorescent dye. Radius of the dye begun to decay after some time with the decreased of the lighting time, as shown in the Table 1.

TABLE 1  
EMISSION TIME AT 321(K)

Experience No.	Lighting time (sec)	Emission time (sec)
1	1	120
2	3	175
3	6	250
4	9	320
5	15	400

#### 2.3.2 The printed area and emission time

As known that the emission time is related directly with the area that is coated by the fluorescent dye, the increase of the fluorescent dyes amount will increase of the molecules which contain the photons that occur the emission. This test was doing by:

Two printed samples with different areas- that the dye is coated- have exposed by fluorescent dye to sunlight for different times per each experience. According to the same times to every sample at a surrounding temperature degree about (325 K). Then the sample was transferred to a dark place at temperature degree about (305 K), and calculated the emission time of the sample until the decay of the light from the fluorescent dye. The radius of the dye begun to decay after a specific time according to the exposure printed areas of the fluorescent dye, as shown in the Table 2. It is clearly that the emission time was changing with the changing of the printed area. The temperature degree is taken by thermal sensors touching the samples surface.

TABLE 2  
EMISSION TIME BY DIFFERENT PRINTED AREAS.

Sample Area (cm <sup>2</sup> )	Lighting Time (sec)	Emission Time (sec)
83.3	2	360
13.5		120
83.3	15	660
13.5		320
83.3	30	750
13.5		420

### 2.3.3 The change in temperature due to radiation heat transfer rate

This test gives the amount of the energy which is emitted by radiation from the printed fabric with printed by fluorescent dye, the fluorescent dye absorbs the energy from the light beam that has fallen on it, this energy include thermal energy that is called radiation heat transfer. In this research the fabric is treated like the ideal gray body, by knowing the temperature of the fluorescent printed fabric surface, its area. Applied these conditions on several samples with an area (83.3 cm<sup>2</sup>), and applied of the following equation 3,

$$q_{rad} = \epsilon \sigma (T_s^4 - T_{sur}^4) \quad (3)$$

where  $\epsilon$  is a radiative property of the surface termed the emissivity. With values in the range  $0 \leq \epsilon \leq 1$ , for this fabric it is (0.77),  $T_s$  is the absolute temperature (K) of the surface,  $T_{sur}$  is the temperature of the surrounding, and  $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$  is the Stefan. Boltzmann constant Such a surface is called an ideal radiator or blackbody. The temperature of the cloth was raised by the heaters, and the radiation heat transfer values as shown in the Table 3, when the surrounding temperature was (303 k).

TABLE 3  
 THE CHANGE IN TEMPERATURE

Experience No.	Temperature (K)	Radiation heat transfer (W)
1	321	$78.6 \times 10^{-8}$
2	317	$61 \times 10^{-8}$
3	313	$43.7 \times 10^{-8}$
4	308	$21.8 \times 10^{-8}$

### 2.3.4 Life time Due To The decay of the intensity

The lifetime is important, as it determines the time available for the fluorophore to interact with or diffuse in its environment, and hence the information available from its emission. Were taken two samples with different color of fluorescent dyes. Green and yellow color, where the decay coefficient of the green color (83000). Whereas the decay coefficient of the yellow color (73000). They exposed to the different time of light, and calculated the intensity at each time by applied the equation (2)

$$I(t) = \alpha e^{-t/r} \quad (2)$$

The increase of the lighting time led to decrease of the fluorescent dye life time. The result shown in the Table 4.

TABLE 4  
 LIFE TIME DUE TO INTENSITY

Sample Color	Emission Time (sec)	LifeTime (sec)	Intensity ( $I_t$ )	Lighting Time (sec.)
Green	120	$83 \times 10^{-4}$	$7.27 \times 10^{-22}$	0.5
Green	330	$30 \times 10^{-4}$	0	6.5
Green	600	$17 \times 10^{-4}$	0	12
Yellow	150	$66 \times 10^{-4}$	$1.4 \times 10^{-93}$	1.5
Yellow	180	$55 \times 10^{-4}$	0	2
Yellow	400	$25 \times 10^{-4}$	0	10
Yellow	4600	$2.17 \times 10^{-4}$	$4.03 \times 10^{-10}$	120

## 3. Results and Discussion

### 3.1 Lighting time towards emission time

When the fluorescent printed fabric exposed to light beam for a certain period of time, and then put it in a dark place. The fluorescent dye released light with a specific color according to the color of the dye material. After a certain period of time, the light began to fade little by little, due to the decay time by the emission of photons.

When the fluorescent dye exposes to light, number of excited electrons will be raised. With increased the lighting time the number of raised electrons will increase, and the emission time will increases too. As shown in Figure 3, the relationship between the increase of the lighting time and the emission time as a curved extrusive shows the increasing of decay time of the fluorescent dye when it put in a dark place after exposure it to a light for some time.

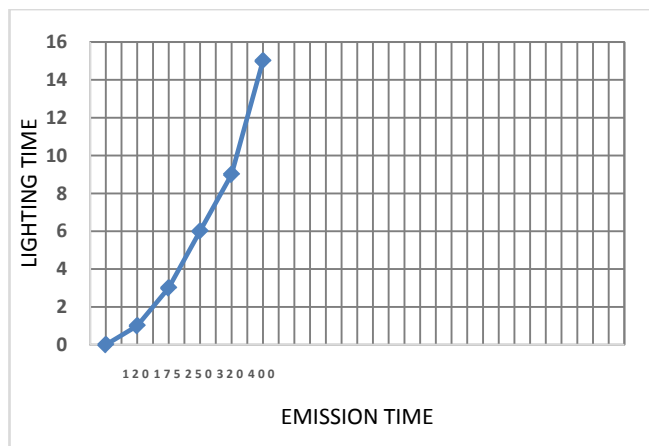


Fig.3. Lighting time towards emission time

### 3.2 The Printed area towards the Emission time

This type of dyes related to the raised electrons numbers. Thereby increasing the area of the printed fabric will be increases the fabric surface witch contact with the light. Therefor more electrons will raise, and increases the emission time by the increase of photons, as in the lighting increase, that is clear in Figure 4. Where the increased of the printed area about six times would increase the emission time about (2-3) times, i.e. with the increases of the printed samples the emission time will increases too, so the small prints on the clothes will not give a good emission especially from far places because that prints will not show clearly, the thick lines will give the requested effect especially in police uniform.

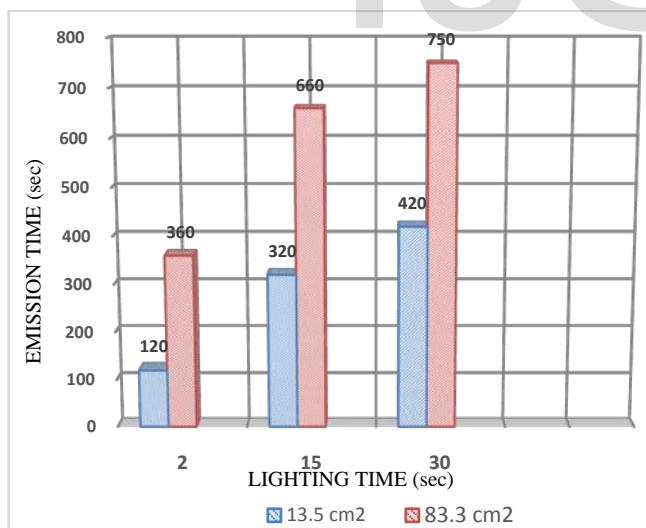


Fig. 4. The printed area towards the emission time

### 3.3 The change in Temperature to Radiation Heat Transfer

When the temperature becomes higher the fabric surface temperature will rises, and this leads to increase the energy emitted from radiation, so the radiation heat transfer values increase(15%), as shown in Figure 5. when the temperature raised from (308 to 321)K.

As known that the light releases specific heat According to the intensity and time of continuance. So increases of the lighting time, will increases the temperature, and increases the radiation heat transfer because of increase the number of the heat air molecules around the cloth, and increases of the light from the printed area, i.e. the increase of the lighting time leads to rise the temperature of the cloth and increase the radiation heat transfer.

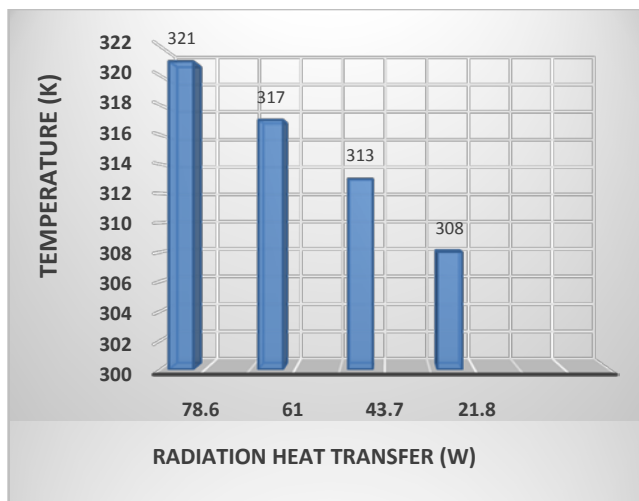


Fig. 5. The Change in temperature to radiation Heat Flux

### 3.4 Life Time due to Intensity at time

From calculated fluorescence dye life time and intensity at time as shown in table 4, for two colors of fluorescent dyes that different of decay coefficient. As shown in Figure 6. The intensity values were very small, and these values were very closed to zero like shown in the line graph in figure 6, intensity values were constant at the times (12-10-6.5-) seconds, where the life time values were (17-25-30-55)  $\times 10^{-4}$ , because the time values were small, but at the point that the life time was (66  $\times 10^{-4}$ ), the intensity at time (t=1.5 second) increased to reach to the value (1.4  $\times 10^{-93}$ ). The increased is cleared to be at point [intensity= 7.27  $\times 10^{-22}$ , & life time=83  $\times 10^{-4}$ ]. So as the lighting time was increased to (120 seconds) the intensity at that time was also increased to be (4.03  $\times 10^{-10}$ ). See equation (2). I.e. the lighting time values must be very big to give clear intensity values, and the intensity at time increase with the lighting time increasing in a big values. The lighting time is the most important parameter of the fluorescent dyes emission properties.

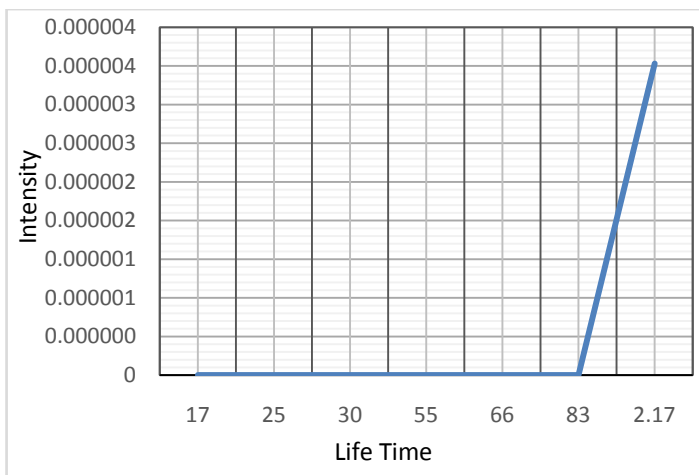


Fig. 6. Life time due to Intensity

#### 4. CONCLUSIONS

1. The emission time of the fluorescent dye increases with increasing the lighting time.
2. Increasing the lighting time leads to raise more than number of electrons, and increases the emission time.
3. When the Fluorescent Dye printed area is increased, the emission or decay time will increase at a rate of a half the increase of the area.
4. The emitted energy values from the fluorescent dye Increases with increasing temperature of the catalyst optical, due to the Thermal energy generated by the light. Thus, the radiation heat transfer rate increases (15%) for each temperature increase of 12 Kelvin.
5. Use this type of dyes on fabrics give the fabrics Function feature. Giving optical signal to show the person place in the dark. So it is used in policemen suites.
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#### Reference

- [1] Joseph, R. Lakowicz, Principles of Fluorescence Spectroscopy, 3rd edition, USA, 2006.
- [2] V. Buschmann, D. Weston, and M. Sauer, Spectroscopic Study and Evaluation of Red-Absorbing Fluorescent Dyes, Bioconjugate Chem. USA. Volume 14, 2003.
- [3] M. Bruchez, Semiconductor Nanocrystals as Fluorescent Biological Labels, SCIENCE, Volume 281, NY. 1998.
- [4] Y. Lin, W. Lin, and H. Chen, A Unique Class of Near-Infrared Functional Fluorescent Dyes with Carboxylic-Acid-Modulated Fluorescence ON/OFF Switching: Rational Design; Synthesis; Optical Properties; Theoretical Calculations; and Applications for Fluorescence Imaging in Living Animals, Journal of the American Chemical Society, Volume 134, US. 2012.
- [5] K. Chidambaram Venila, A. ZainulZakariab, and A. W. Ahmada A., Bacterial pigments and their applications, Elsevier Process Biochemistry; Volume 48; Malaysia, 2013.
- [6] L. Howard Needles, Textile Fibers, Dyes, Finishes, and processes , 1st edition, California , 1986.
- [7] F. Craig Bohren, Fundamentals of Atmospheric Radiation: An Introduction with 400 Problems, 1st. ed. NY. 2006.
- [8] B. Berlin, P. Kay, Basic Color Terms: Their Universality and Evolution, Berkeley, University of California Press, California, 1969.
- [9] G. Donald, C. Holl, and B. Robert, Photoluminescent Material Evaluation; Technical Information Service (NTIS); Springfield; Virginia 22161:US, 2009.
- [10] B. Peter, Chromic Phenomena The Technological Applications of Colour Chemistry. 1st. ed. UK, 2001.
- [11] J.Rietdorf, Microscopic Techniques. Advances in Biochemical Engineering; Biotechnology. Berlin: Springer; Volume 95. NY. 2005.
- [12] B. James Pawley, Handbook of Biological Confocal Microscopy, 3rd ed. NY. 2006.
- [13] D. Hossain, M. Rashid, A. Kafi, and F. Sarker, Investigation on Physical Properties of Fluorescent Dyed Cotton Knit Fabric, Chemical and Materials Engineering Volume 2(5), pp. 101 - 105, Horizon Research Publishing, US. 2014.
- [14] M. Warren Rohseow, P. James Hartnett, and I. Cho Young, Handbook of Heat Transfer, 3rd. ed. NY, 1998.
- [15] L. Theodore, S. Adrienne, P. Frank, and P. David, Fundamentals of Heat and Mass Transfer , 7th edition, USA, 2007.

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