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A Simple Inexpensive Designing Process of Diffuser Suitable for LED Tube

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ABSTRACT

Uniform illumination is an essential optical requirement for Light Emitting Diode (LED) lighting. This paper presents a simple, inexpensive designing procedure of efficient diffuser for uniform illumination of LED tube light. We demonstrate here some acid etched ordinary glass diffusers, and study the uniformity and absorption coefficient of these diffusers to compare their performance with till date market available diffusers. To achieve this goal, model samples were prepared by etching. Etched surfaces were observed by optical microscopy and scanning electron microscopy (SEM). Surface morphology was used to examine the grains size of the etched surface of the tubes. Our investigation showed that grain size and absorption coefficient of the surface increased with the increase of the etching time. Uniformity of the etched diffusers also increased with the increase of the etching time and reaches to a certain optimum level with 16 minute etched tube. Absorption coefficient at this level is just 8.66%, while it is 17.14% to 31.27% for different market available diffusers.

Keywords: Light Emitting Diode (LED), Diffusers, Etching, Illumination, SEM, Absorption Coefficient.

1. Introduction

Now a days, white Light Emitting Diodes (White LEDs) have clearly emerged as an alternative solid- state- light sources. It gradually becomes the premier choice in lighting solutions because of its following advantages over traditional light sources - i) Less greenhouse emissions, ii) Unlike CFL and Fluorescent lamps, turns on instantly, iii) High energy efficiency, iv) Durability, v) large ON/OFF cycles and vi) long life (typically > 50000 Hrs.) [1-10]. In spite of these great advantages, the adoption of high efficiency LED light has been slowed somewhat for household use due to its one disadvantage. The disadvantage is, the light emitted by the LED light sources is focused and harsh [11]. Thus to provide softer and warmer light, there is a need for diffusers for spreading concentrated light [5, 12]. But choosing material for diffusers is a difficult task because material additives for light diffusion can impact on light transmission and vice versa [13].

Literature survey shows that there are two types of glass diffusers– sandblasting glass diffuser and engineered holographic diffusers [11]. In the sandblasting glass diffuser, grain size is large and the grain sizes are uncontrollable. The absorption coefficient of this type diffuser is also large. On the other hand engineered holographic diffusers are costly [12]. In the market a few number of LED lighting diffusers are available, but carefully observed study showed that their absorption is appreciably high and some of them are costly also. Therefore, the aim of our study is to design a low cost LED diffuser with higher uniformity and lower absorption. In this paper, we reported the detail methods of designing a low cost acid etched glass diffuser. We next investigated about the absorption and the uniformity of those diffusers. The effect of the acid on the grain size of the etched glass due to variation of etching time has also been investigated. It is expected that this investigation will help light industries to supply better quality LED lamps and tube lights at lower cost.

2. Experimental section

2.1. Designing procedure

To prepare the model samples we etched some chemically cleaned long ordinary glass test tubes by hydrofluorosilicic acid (H_2SiF_6) for various times (8, 9, 10, 12, 14, 16 and 18 min.). Hydrofluorosilicic acid was synthesized by following the method as reported in [14]. Typically, the mixture of 0.128 M CaF_2 (Sigma Aldrich - 99.99% trace metal basis), 0.166 M dry quartz sand (Diamond Stone Industries) and 0.656 M concentrated H_2SO_4 (Sigma Aldrich - 99.999%) was heated carefully at about 100°C. The escaped silicon tetrafluoride (SiF_4) gas was led through a washing bottle containing 2ml concentrated H_2SO_4, and then into a porcelain dish. A small vessel with mercury was placed at the bottom of the dish. After dipping the gas tube into mercury, 50ml distilled water was pored over it. It was due to assurance that gas cannot emerge directly at water, as it hydrolyze silicon tetrafluoride and yield silicon dioxide, which may clog the outlet tube. After ceasing of gas emission, the hydrofluorosilicic acid, which was separated in water, was filtered and washed with a little amount of water. The acid getting in this way was cloudy. To remove the remaining silicon dioxide the cloudy acid was again filtered through folded filter. The conversion to hydrofluorosilicic acid can be described as -
$3SiF_4 + 2H_2O = 2H_2SiF_6 + SiO_2$.

After completion of the desired time for etching the tubes were rinsed immediately, at first by baking soda solution, prepared by adding 100 gm baking powder to 2 liter water, for 5 minute and then by cold water for 15 minute, to neutralize the hazardous hydrofluorosilicic acid and to remove the cling acid on the rough surface of the etched tube. The treated specimens were also sonically cleaned in distilled water for 10 minute. The tubes are then dried in air at room temperature.

As hydrofluorosilicic acid is hazardous to health, the entire process was done by wearing acid resistance gloves, plastic apron and musk.

The samples for SEM study were prepared on (1cm × 1cm) ordinary glass slides at the same time in the same manner as mention above. The SEM images were recorded in a ZEISS SEM (EVO 18) operating at 10kV.

2.2. Experimental setup

To characterize the optical diffusion properties of the model diffusers we measured the intensity of the LED source at different scattering angle, with and without diffuser. Figure 1 shows the experimental setup we have made for this purpose. S is a large semicircular aluminium strip, prepared by bending a straight strip after drawing 180 equidistance lines on it and L is a LED Panel, which acts as a bright light source. The LED panel was made by connecting 10 white LEDs (5730) in series on a printed circuit board (PCB). The length of the LED panel was just as that of the etched tube and the width of it was slightly smaller than the diameter of the tube. The LED panel was placed at the center of the strip (S) with its axis perpendicular to the diameter of the strip.

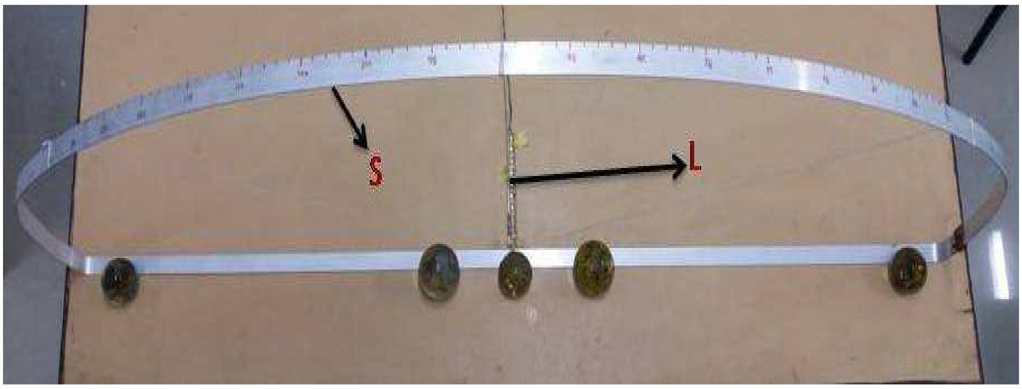

Figure 1. Experimental set up for measuring intensity at different scattering angles.

3. Result and discussion

3.1. Scanning electron microscopy (SEM) study

The morphology of the etched surface was studied under a ZEISS scanning electron microscope (SEM) (EVO 18) operated at 10kV. Figure 2A – D shows the typical micrographs of the etched glass surfaces for different etching times. The SEM micrographs clearly revealed that there evolved some grains due to the effect of hydrofluorosilicic acid and the sizes of the grains are different for different etching timings. The average sizes of the grains for different etching period are presented in Table 1. It shows that the average grain size of the hydrofluorosilicic acid etched glass surface increases with the increase of etching period.

3.2. Study of angular distribution of optical intensity

A set up as shown in Figure 3 was used to measure the angular distribution of optical intensity. The angular measurements of optical intensity were made by rotating a lux – meter on the pre-scaled aluminium strip. At first the angular measurement was done for direct LED Light i.e. without covering the LED panel by any diffuser, then the same process was repeated by covering the LED panel by 8, 9, 10, 12, 14, 16 and 18 minute etched tube, and I, II, and III type market available differs. Among the three types of available diffuser first one was made of thin polycarbonate, second one was of relatively thick polycarbonate and the third one was glass coated. Figure 4 shows the angular distribution of intensity of LED light for different samples. For studying absorption property of the diffusers we measured the absorption coefficient of the diffusers. The absorption coefficient was measured from the intensity distribution curve using the relation –

$$\text{Absorption coefficient} = \frac{\text{area of direct light curve} - \text{area of the diffuser curve}}{\text{area of direct light curve}} \times 100\%$$

The absorption coefficients of different diffusers are presented in Table 2.

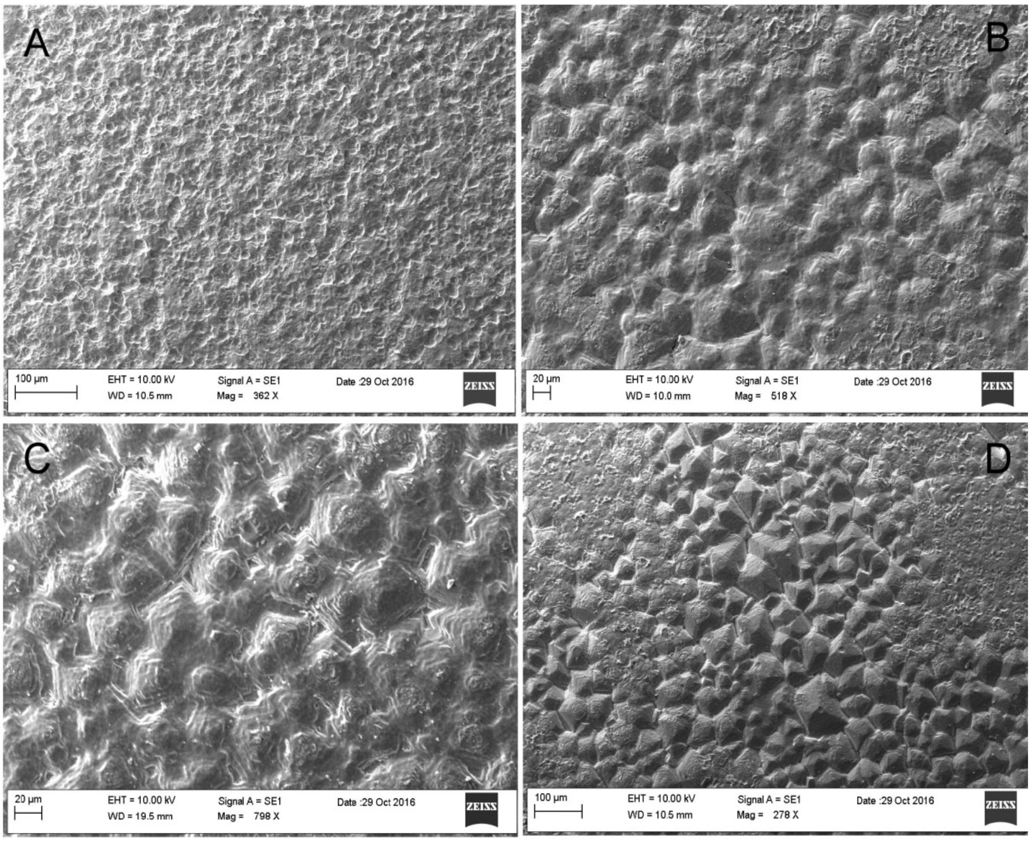

Figure 2. SEM micrographs of the hydrofluorosilicic acid etched glass surface for different etching time. A = 8 min etching, B = 10 min etching, C = 16 min etching, D = 18 min etching.

Table 1. Average grain sizes of the glass surface after etching with hydrofluorosilicic acid for different etching period.

Surface treatment (Etching time in Mins)	Average size of the grain (µm)
8	15.79
10	20.36
16	26.53
18	35.83

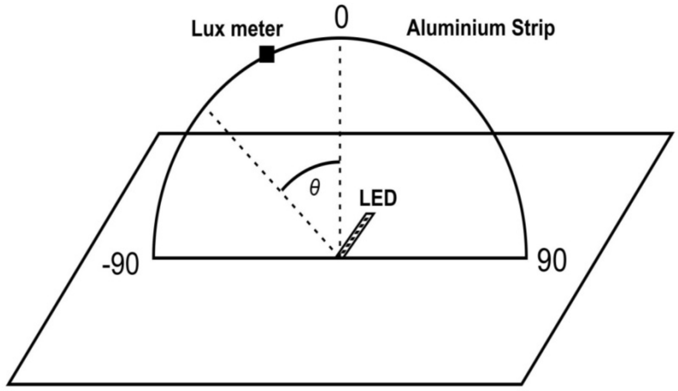

Figure 3. Schematic diagram of the experimental arrangement

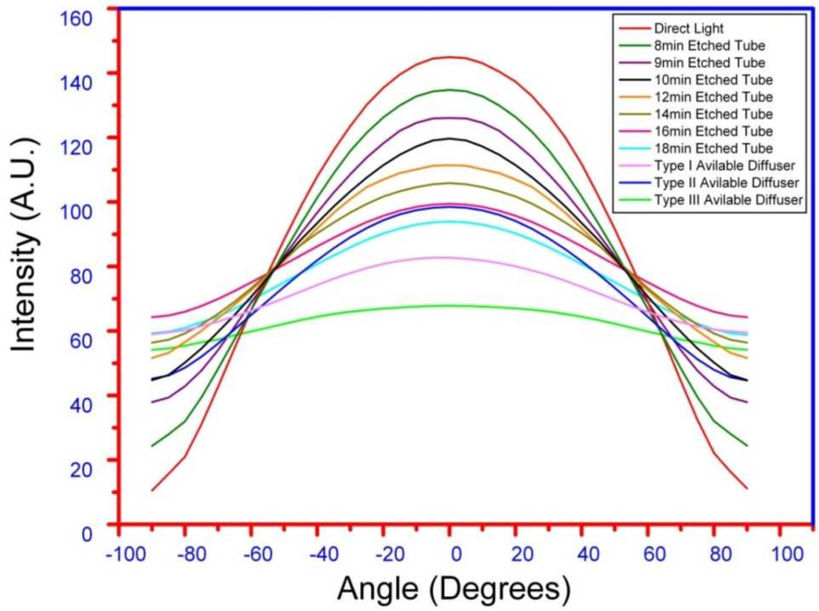

Figure 4. Angular distribution of intensity of LED light for different samples.

Table 2. Absorption coefficient of different diffusers calculated from intensity distribution curve.

Type of diffuser	Absorption coefficient (%)	Width (degree)
8 min. etched	3.4	115
9min. etched	4.5	125
10 min. etched	5.56	135
12 min. etched	6.08	165
14 min. etched	7.52	180
16 min. etched	8.66	180
18 min. etched	14.67	180

I type available	17.14	155
II type available	21.05	180
III type available	31.27	180

Figure 4 clearly shows that hydrofluorosilicic acid etched tube spread the concentrated LED light and the uniformity of the proposed diffuser increases with the increase of etching time up to 16 minute etching. There after intensity distribution becomes saturate. The absorption coefficient of the diffusers increases with the increase of etching time. The width of the spreading also increases with the increase of etching period and becomes 180 degree for more than 14 minute etching.

4. Conclusion

In this study a simple method has been developed to design LED light diffuser by acid etching method. The algorithms of the designing method have been presented in details. The technique is simple and inexpensive. SEM micrograph reveals that the grain size of the etched glass surface increases with the increase of etching period. Studies of angular distribution of intensity show that uniformity of the fabricated diffusers increases with the increase of etching time up to an optimum level for 16 minutes etching. Observations show that the absorption coefficient of the diffuser increases with the increase of the grain size. It is also revealed that the width of the spreading increases with increase of etching period and becomes 180 degree for etching periods greater than 14 minute. Present investigations show that although the intensity distribution curve of some market available diffusers are a little flatter, but their absorption coefficient is much greater than the fabricated diffusers. E.g., it is just 8.66% for the fabricated diffuser with 16min etching, while for the market available diffusers it is about 17.14% - 31.27%. Thus we can conclude that a 16 minute hydrofluorosilicic acid etched glass tube can be used as a diffuser for LED lights, which will increase the efficiency of the LED lights.

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