Preparation of doped microstructure diffusing film by photocuring micro-imprint

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Abstract. In this paper, the process of preparing of doped diffusion film by ultraviolet curing micro-embossing was studied. The preparation method of microstructure diffusion film by photo-curing micro-embossing is different from the traditional methods. The effect of irradiation time on the apparent quality and the effect of the percentage of light diffusing agent on the optical properties and tensile properties of the diffusion film were investigated. The results shown that under the condition of 365 nm ultraviolet light wavelength and a light intensity of 800 mW/cm², the apparent quality of the diffusion film was good. When the irradiation time was 6 s; and the content of the diffusing agent was 30%, the optical performance was relatively good; the larger the content of the light diffusing agent, the smaller the tensile strength of the diffusing film.

1. Introduction

The light diffusing film is an optical film which can uniformly distribute the emitted light. The light-diffusing film is based on the principle of reflection, refraction and scattering between different dielectric materials when light passes through the light-diffusing film, thereby diffusing the light [1], eliminating glare, and make the light softer. With the advancement of science and technology, light diffusion films have been widely used in liquid crystal display technology, beam shaping [2-3], inorganic light emitting diodes [4-8] and photovoltaic devices [9-11]. Therefore, it has become the focus of research in the related fields.

At present, there are various methods for preparing microstructures on the surface of a diffusion membrane, mainly including chemical etching, laser engraving, micro-injection [12], and hot stamping [13] and so on. However, there are still some problems with these methods. Such as using the chemical etching method, the surface of the diffusion film is not smooth enough, and the uniformity is difficult to control for large-area preparation. Laser engraving has the disadvantages of low production efficiency and difficulty in mass production. The disadvantages of the micro-injection method is that the mold is complex and costly, and is difficult in manufacturing a large-area diffusion film. And the hot stamping process is complicated and requires heating and cooling during processing, which easily causes thermal...
deformation of the diffusion film, resulting in low molding precision of the product. Therefore, in this paper a UV-curing micro-imprinting method to prepare a doped diffusing film was proposed. The UV-curing micro-imprinting process uses the photosensitive material which is a liquid at room temperature and there is no need to heat and cool during the molding process, thus high molding efficiency, energy saving and environmental protection can be achieved. Therefore, the UV-curing micro-imprinting process provides a way to prepare a diffusing film with good light diffusibility, good tensile properties and good apparent quality.

In the experiment, the doped micro-structured light-diffusion film was studied. The light-diffusing agent exists on the surface or inside of the diffusion film. So the light can shift between the materials with different refractive indexes to achieve the diffusion effect and optical performance. The method of making diffusing film by UV-curing micro-imprinting has the advantages of fast forming, high efficiency, low cost, green environmental protection and has a broad market application prospect.

2. Experimental Preparation

2.1. Main Raw Materials
Ethyl ethoxyacrylate: EOEOA, Changshu Hengrong Trading Co., Ltd.; Trimethylolpropane triacrylate: TMPTA, Changshu Hengrong Trading Co., Ltd.; Bifunctional urethane acrylate, LE-6702, Inspirational Chemical Co., Ltd.; Hexafunctional urethane acrylate, LE-6706, Inspirational Chemical Co., Ltd.; 2-hydroxy-2-methyl-1-phenyl-1-propanone: 1173, Changshu Hengrong Trading Co., Ltd.; 3-leveling agent, BYK-333, Guangzhou Zhongwan New Material Co., Ltd.; 4-organosilicon light diffusing agent: Dongguan Kemai New Material Co., Ltd.

2.2. Main Equipment
Ultraviolet light source radiation system, homemade; Light curing micro-imprinting machine, homemade; UV light source, Shanghai Runzhu Electronic Technology Co., Ltd.; 10,000-point electronic scale, ME104E, Olympus Industrial Co., Ltd.; High-speed spin coating machine, KW-4A, Institute of Microelectronics, Chinese Academy of Sciences; Laser confocal microscope, OLS5000, Olympus Industrial Co., Ltd.; Scanning electron microscope, HITACHI-S4700, Hitachi, Japan.

2.3. Preparation of diffusion membrane
2.3.1. Preparation of Photocurable Materials
First, urethane acrylate, ethoxyethyl acrylate (EOEOEA), tripolyethylene glycol diacrylate (TPGDA), photoinitiator (1173) and leveling agent (BYK-333) were thoroughly mixed under a certain ratio. Second, a certain amount of a silicone light diffusing agent was added in. Then uniformly mixed by a magnetic stirrer. At last the photocurable materials containing the light diffusing agent was obtained.

2.3.2. Experimental Steps
(1) The prepared photocurable materials is vacuumed and defoamed, and the bubbles are removed and taken out for use.
(2) Uniformly coating the prepared photocurable resin on a PC substrate and imprinting it with a smooth PDMS mold.
(3) Set the illumination intensity and irradiation time of the ultraviolet light source, turn on the ultraviolet light source, irradiate the mold, and the coating under the mold will be solidified.
(4) After the coating is completely cured, the PDMS template is released from the surface of the substrate to obtain a photocured microembossed product.
(5) Microscopic analysis and characterization of the diffusion membranes obtained under different process conditions.

3. Results and Discussion

Fig. 1 is the result of microscopic investigation of the cross section of the diffusion film by a scanning electron microscope. As it can be seen from Fig. 1, the diffusion particles are uniformly distributed in the photocurable material.

![Figure 1. Dispersion of light diffusing agent](image)

3.1. Influence of irradiation time on the apparent quality of the diffusion film

In this study, an ultraviolet light source with a wavelength of 365 nm and a light intensity of 800 mW/cm² was used to investigate the effect of irradiation time on the apparent quality of the diffusion film. The irradiation time was 2s, 3s, 4s, 5s, and 6s, respectively, a microscopic morphology of the surface of the diffusing film is shown in Fig. 2.

![Figure 2. Micrograph of the light diffusing film at different irradiation times](image)

(a) 2s  (b) 3s  (c) 4s  (d) 5s  (e) 6s

It can be seen from Fig. 2 that when the irradiation time was short, the rugged shape appeared, the curing of the photocurable material was incomplete. And with the increasing of irradiation time, the curing degree of the photocurable material was improved. When the irradiation time reached to 6s, the
photocurable material was completely cured, the apparent quality of the diffusion film was good, and at the same time the molding efficiency was ensured.

3.2. The effect of the percentage of light diffusing agent on the optical properties

The percentage of light diffusing agent has a great influence on the optical properties of the diffusing film. In the experiment 5 μm particle size of the light diffusing agent was used, the adding amount of the diffusing agent was 10%, 20%, 30%, 40%, 50%, respectively. The optical properties of the diffusion film were evaluated by the light transmittance and haze, and the results were shown in Fig.3.

As shown in Fig.3, when the percentage of the diffusing agent added was 10%, the transmittance of the diffusing film was 82.53%, and the haze was 69.81%. With the increasing of the percentage of the diffusing agent added, the haze gradually increased and the light rate decreased. However, when the content of diffusing agent was too high, the light diffusing agent scattered and reflected the light multiple times, and the light energy loss was severe. When the percentage of the light diffusing agent increased to 40%, the haze of diffusion film reached to 90.49%, increased by 20.64%, and the optical performance was better.

3.3. The effect of percentage of light diffusing agent on mechanical properties

In practical applications, not only the optical properties of the diffusion film are required, the mechanical properties are also required. This section explored the effect of the percentage of light diffusing agent on mechanical properties. The effect on the tensile strength of the diffusion film was tested under different diffusion agent contents. The result was shown in Figure 4.

As shown in Fig.4, with the increase of diffuser content, the mechanical properties of the diffusing film gradually decreased. When the content of the light diffusing agent was 20%, the tensile strength was 18.8 MPa, and when the percentage of the light diffusing agent increased to 40%, the tensile strength was 14.8 MPa, which reduced by 4 MPa. Because with the increase of diffuser content, some of the particles may be mixed unevenly and resulted in agglomeration.

4. Conclusions

In this paper, the effects of illumination time and diffuser content on the apparent quality, optical properties and mechanical properties of the diffusion film were studied.
(1) When the illumination time was short, the curing of the material is incomplete. With the increasing of illumination time, the curing degree of the photocurable material increased. When the illumination time was 6s, the photocurable material was completely cured and the apparent quality was good.

(2) As the percentage of diffusing agent increases, the haze gradually increases, and the light transmittance decreases. However, when the diffusing agent content is too high, the optical energy loss is severe. When the percentage of the light diffusing agent is 30%, Good optical and mechanical properties are obtained.

(3) With the increasing of diffuser content, the mechanical properties of the diffusing film gradually decreased.

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