Study on Preparation of Microlens Array Hydrophobic Film by Ultraviolet Curing Micro-imprint

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Abstract. In this paper, the formation process of microstructure array hydrophobic film prepared by ultraviolet curing imprinting was studied. The UV-curing micro-imprinting method was used to replace the traditional hot stamping method to prepare the micro-structured hydrophobic film. The effects of illumination time and intensity on the surface hydrophobicity were investigated. Results shown that the micro-structure hydrophobic film prepared by UV-curing micro-imprint has high replication precision and good hydrophobic effect. With the increase of illumination time, the water contact angle of the product increased and reached 125° at 30s illumination time. With the increase of the illumination intensity, the water contact angle of the micro-imprinted product was also gradually increased.

1. Introduction

With the development of science and technology, the living standards of Chinese people are improved continuously. Their demand for functional materials continues to increase. Hydrophobic film has excellent properties such as hydrophobicity¹, self-cleaning property², ice-suppressing property³, drag reducing property⁴ and corrosion resistance⁵ and so on. It makes it widely used in people's daily life. For example, it can be applied to the surface of building glass to achieve self-cleaning effect, save water resources and avoid the danger of workers working at heights. It can be used in aircraft and outdoor buildings to provide anti-icing function. It can be applied to metal surfaces to make it corrosion resistant. It can also be used in medical protective fabrics to reduce bacterial transmission and so on. Therefore, hydrophobic materials have a very broad application prospect in the fields of construction, daily life, and aerospace and so on⁶.

Surface microstructure has an important influence on the hydrophobicity of the product. There are various ways to prepare microstructure on the surface of the product, mainly includes template⁷, electrospinning⁸, spraying⁹, etching¹⁰, self-assembly¹¹ and so on. However, there are some shortcomings with the above preparation methods. For example, equipment and materials are expensive and the production cycle is long, and so on.
In this study, a hydrophobic film was prepared by ultraviolet curing micro-imprinting. The UV-curing micro-imprinting process is a novel method with simple equipment and easy operation. The micro-structure is obtained by rapid imprinting and UV-cured under normal temperature and pressure. It has the advantages of rapid molding, low cost, environmental protection, high molding precision, and has a good application prospect.

2. Experimental Preparation

2.1. Main Raw Materials
Silicone resin, YL-1, Laiyang Yulin Chemical Co., Ltd.; Polyurethane acrylate, prepolymer, Jiangmen City Inspiration Co., Ltd.; Ethoxyethyl acrylate, monomer, Taiwan Changxing Chemical Industry Co., Ltd.; 2-hydroxy-2-methyl-1-phenyl-1-propanone, 1173, Taiwan Changxing Chemical Industry Co., Ltd.; BYK-333, leveling agent, Guangzhou Zhongwan New Material Co., Ltd.; Polydimethylsiloxane, PDMS, Dow Corning, USA.

2.2. Main Equipment
Light curing micro-imprinting machine, homemade; Ultraviolet light source radiation system, homemade; UV light source, Shanghai Runzhu Electronic Technology Co., Ltd.; Electronic balance, FR124CN, Ohaus, USA; Vacuum drying oven, ZK-35ASB, Beijing Kewei Yongxing Instrument Co., Ltd.; Contact angle measuring instrument, JC2000D, Beijing Zhongyi Kexin Technology 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, Japan Electronics Co., Ltd..

![Homemade light curing micro-imprinting equipment](image1.png)

2.3. Experimental Process
2.3.1. Preparation of Photocurable Materials
The urethane acrylate, ethoxyethyl acrylate, 2-hydroxy-2-methyl-1-phenyl-1-propanone, and a leveling agent were thoroughly mixed under a certain ratio, then defoamed under vacuum for one hour.

2.3.2. Experimental Steps
(1) UV-curable material was evenly coated on the PC chip, then the PDMS mold was pressed onto the UV-curable material.
(2) The illumination intensity and time of the ultraviolet light source were set, the above PC chip with UV-curable material was irradiated.
(3) After the UV-curable material was completely cured, the PDMS soft template was released from the surface of the substrate to obtain a micro-structured film product.
(4) The properties of the films prepared under different conditions were analyzed separately, and the water contact angle of the micro-imprinted products was measured by a contact angle measuring instrument.

3. Results and Discussion

The Surface morphology of PDMS mold observed by laser confocal microscope and SEM was shown in Fig. 2.

![Surface morphology of PDMS mold](image)

(a) three-dimensional topography  (b) SEM

**Figure 2.** Surface morphology of PDMS mold

3.1. Effect of illumination time on surface hydrophobic properties

At 0.2Mpa imprinting pressure and 1000mW/cm² UV light intensity, and the UV irradiation time 15s, 20s, 25s, 30s and 35s, respectively, the corresponding water contact angle on the products with the micro array structure prepared in this research was shown in Fig. 3.

![Effect of different illumination time on water contact angle](image)

**Figure 3.** The effect of different illumination time on the water contact angle of micro-imprinted film

From Fig.3 the change of the water contact angle of the surface with array micro-structure under different illumination times can be obtained. It shown that with the illumination time increasing, the water contact angle increased, at 30 s illumination time, the water contact angle reached to a maximum of 125°. The water contact angle images of the product measured by the water contact angle measuring instrument were shown in Fig.4.

![Contact angle images](image)

(a) 15s  (b) 30s

**Figure 4.** The contact angle of film products with different illumination time
3.2. Effect of light intensity on surface hydrophobic properties

The imprinting pressure was set to 0.2Mpa, the illumination time was 30s, and the maximum ultraviolet intensity was 1000mW/cm². The UV intensity was set to 60%, 70%, 80%, 90%, 100% of the maximum light intensity, respectively, during the imprinting processing. The change of the water contact angle of the films with micro array structure was shown in Fig.5.

![Figure 5](image_url)

**Figure 5.** Effect of UV light intensity on the water contact angle of micro-imprinted film

It can be seen from Fig.5 that as the UV intensity increases, the water contact angle of the film with microstructure increases. Because the microstructure on the film needs a certain amount of irradiation energy to be fully cured. If the microstructure on the article is not fully cured, the replication accuracy is low, and resulting in the low water contact angle. As the light intensity increases, the microstructure gradually completely cured, and the replication accuracy gradually improved. Therefore, the contact angle of the product increase as UV light intensity increases.

4. Conclusions

In this paper, the microstructure array hydrophobic films were prepared by UV curing micro imprinting. The effects of illumination time and light intensity on the hydrophobic properties of the film surface were investigated. Conclusions were as the follows:

1. The surface water contact angle of the product increases with the increase of illumination time. The optimal irradiation time under the conditions in this research was 30s;
2. Irradiation intensity affects the rate of UV-curing reaction. As the light intensity increases, the water contact angle of the film increases. At the condition of 0.2Mpa imprinting pressure, 30s the illumination time, 1000mW/cm² the light intensity, the water contact angle of the film surface was 125°, which achieved a hydrophobic effect.

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