Protection of OLED Lighting with Ultra-thin Glass by Special Silicone Gel

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ABSTRACT

We have developed OLED lighting using ultra-thin glass. Ultra-thin glass is very useful substrate for OLEDs. However, ultra-thin glass has the disadvantage that it breaks easily. It has been found that protecting the ultra-thin glass surface of OLED lighting products with silicone gel improves mechanical durability.

1 Introduction

We have a special silicone gel called "αGEL" which is developed for the purpose of mechanical shock absorption and cushioning in a wide range of applications such as running shoes, automotive, and electronic devices. Furthermore, based on such abundant experiences and expertise in the development of silicone gel, we have successfully developed “OPTαGEL” which is the transparent silicone gel adhesive film for display devices and the other optical applications [1]. OPTαGEL has high level of clear transparency and yellowing resistance, keeping the excellent performance of shock absorption and stress release of αGEL series. Typical properties of OPTαGEL are summarized in Table 1.

Table 1 Typical properties of OPTαGEL.

Property	Condition	Value
Internal transmittance	380~780 nm	99.4 %
Refractive index	23 ºC, 589 nm	1.41
Haze value	25 ºC	0.24
(Thickness500μm)	95 ºC, 1000 hours	0.33
Yellowing Δb* (Thickness:500μm)	95 ºC, 1000 hours	+0.25
Young’s modulus	-	22 kPa

Especially, silicone OPTαGEL will show off the abilities of shock absorption and stress release in a wide temperature range because its temperature dependence on viscoelasticity is enough small under operating condition.

We have been developing OLED lighting using the ultra-thin glass substrate. The ultra-thin glass has been aware that it has excellent gas barrier property, high transparency, and good flexibility while having a problem with mechanical durability as well as a difficulty in handling during manufacturing process because of its fragility. We have reported the way to resolve the handling problem in the OLED manufacturing process [2, 3, 4]. And we also have found that the mechanical durability of OLED lighting with the ultra-thin glass can be improved when it is encapsulated with stainless steel.

In this study, we will report on the further improvement of mechanical durability of OLED lighting product using ultra-thin glass without sacrificing its flexibility. Especially, the impact resistance from the glass direction was focused. Durability tests of ultra-thin glass laminated with stainless steel foil and OLED lighting encapsulated with stainless steel foil were done. The test samples with the surface of ultra-thin glass protected by OPTαGEL with various moduli. Bending stress, pressure stress and shock absorptivity tests were conducted to investigate the fundamental performance of the test samples with OPTαGEL. The mechanical durability tests were the drop impact test with a stainless ball or a ballpoint pen. The mechanical durability was improved by laminating OPTαGEL on the surface of ultra-thin glass. And OLED lighting using ultra-thin glass can be installed in a wide range of application products. Finally unique samples that we created will be introduced.

2 Experiment

2.1 Sample preparation

We used two types of test sample as shown in Fig. 1. The type 1 does not consist of a real OLED layer but is prepared to simulate to an OLED lighting structure. On the other hand, OLED lightning is encapsulated in the type 2. “G-Leaf” manufactured by Nippon Electric Glass was used as an ultra-thin glass. And OPTαGEL was used as a cover film. A polyethylene terephthalate (PET) with 50 or 100 μm thickness or a polycarbonate (PC) with 200 μm was applied as the cover film, because OPTαGEL is not appropriate to be used as the most outer surface due to its tackiness. The thickness of OPTαGEL was 250 or 500 μm and its hardness was 25, 50, 90, or 130, in the unit “1/10 mm” in needle penetration, which was regulated by ASTM D 1321 and JIS K 2207. Storage modulus (G’) and loss tangent (tanδ) of each hardness of OPTαGEL was shown in Table 2. The larger the needle penetration becomes, the smaller its modulus is. The size of the samples was 50mm square. The test samples were set on two kinds of base plate, one is stainless steel and the other is rubber, in accordance with objective of each experiment in this study.

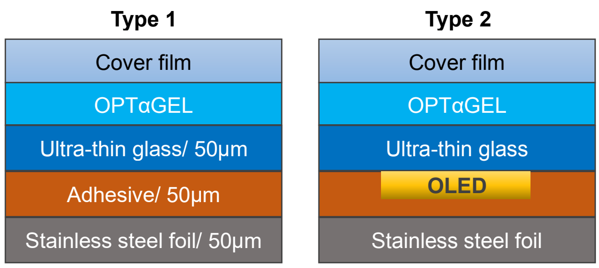

Fig. 1 Test sample configuration.

Table 2 Viscoelasticity property of OPTαGEL.

Property in 10Hz	Needle penetration [1/10 mm]			
	25	50	90	130
Storage modulus G’ [kPa]	82.6	69.1	47.0	30.6
Loss tangent Tanδ [-]	0.083	0.29	0.42	0.58

2.2 Bending stress test

The type 1 samples with 200 μm of PC and 250 μm of OPTαGEL series were pressed on the bending test jig (JM-B-500N, A&D Company, Ltd., Japan) shown in Fig. 2, whose upper fulcrum was R5 mm and lower ones were R2 mm with 40 mm span, by the universal testing machine (AG-X, Shimadzu Corporation, Japan) via 50 N range of load cell in 2 mm/minute of pressing speed.

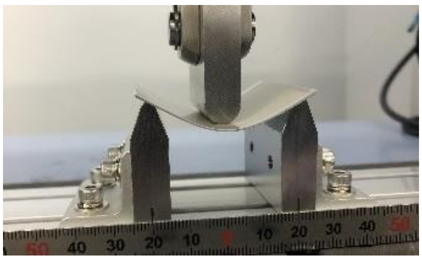

Fig. 2 Bending test jig and a test sample.

2.3 Pressure stress test

In order to investigate the stress release property of OPTαGEL film, static mode of pressing test on the test sample type2 was conducted. A rigid stainless steel base plate was used here to obtain the stress test data to avoid deformation of rubber base. The pressing rod shown in Fig. 3 was made of polyoxymethylene, and its tip size was R0.3 mm. And it was pressed on the samples by the universal testing machine via 50 N range of load cell at a 2.5 N/minute of pressing speed. The sample was kept pressing until the OLED light went out.

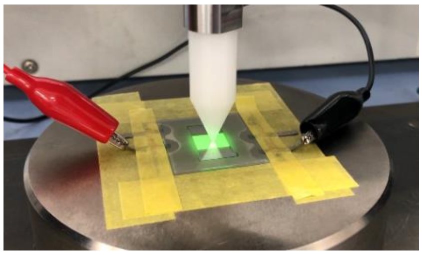

Fig. 3 Pressing rod on the OLED lightning.

2.4 Shock absorptivity test

The type1 samples with 200 μm of PC and 250 μm of OPTαGEL series were tested by the pendulum shock absorptivity testing equipment (PST-300, Shinyei Technology Co., Ltd., Japan) shown in Fig. 4. Each sample was set on the stainless steel base plate and was impacted by the striker at a pendulum angle of 18º and 60 º. When no sample was set on the base plate, each impact acceleration measured by the acceleration sensor was approximately 6,400 or 27,000 m/s^2 corresponding to the pendulum angles of 18º and 60 º, respectively. Shock absorptivity was calculated by the following formula.

$$\text{Shock absorptivity} = 1 - \frac{\text{mpact acceleration with OPT}\alpha\text{GEL}}{\text{impact acceleration without OPT}\alpha\text{GEL}}$$

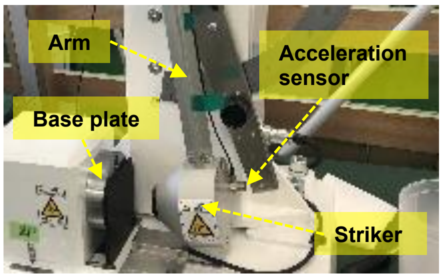

Fig. 4 Pendulum shock absorptivity testing equipment.

2.5 Drop impact test

A stainless ball and a ballpoint pen were used for the drop impact test. The weight of the stainless ball was approximately 64 or 230 g. The diameter of nib on the ballpoint pen, made by BIC Inc., was 0.7 mm. Each of them was dropped on the type 1 of test samples with base plate from 10 cm to 100 cm of height. The base plate was a chloroprene rubber with a shore A hardness of 90 in this test, because it is unlikely that a flexible OLED device is fixed on a quite rigid body. Cracks on the glass were checked in each height level.

3 Results and Discussion

Fig. 5 shows the relationship between the bending force and the pressing displacement depending on the hardness / modulus of the OPTαGEL. Bending force / stress became small as the modulus of OPTαGEL decreased whereas the bending stresses did not show significant difference between needle penetrations n50 and n130. It is expected that the modulus of OPTαGEL can be controlled in accordance with varying requirement for device protection according to device design with keeping its flexibility.

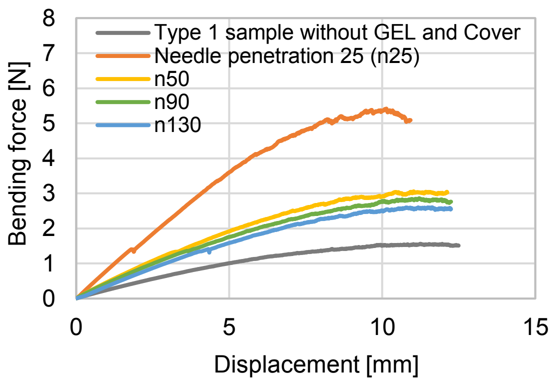

Fig. 5 The relationship between the bending force and the pressing displacement depending on the hardness / modulus of the OPTαGEL.

Fig. 6 shows the relationship between the pressing force and the displacement of the OLED lightning device with the protection layer. Both the pressing force and the displacement on each terminated point with OPTαGEL increased compared with the sample without protection layer. The thicker OPTαGEL or the PET film was, the larger the pressing force on the terminated point. And each curve of thicker 100 μm of PET film deviated upwards from each curve of thinner one. This curve deviation means that OPTαGEL can receive the pressing force in wider area. From the above, OPTαGEL can effectively release the stress on the ultra-thin glass.

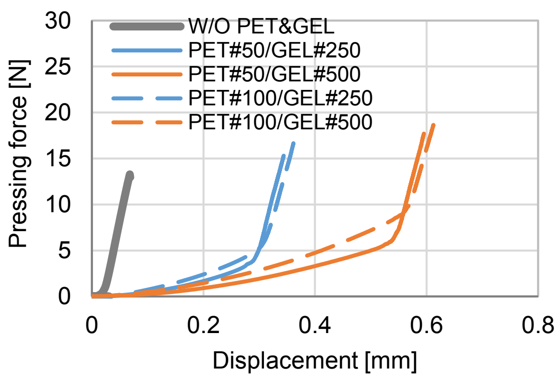

Fig. 6 The relationship between the pressing force and the displacement of the OLED lightning device with the protection layer.

Shock absorptivity depending on hardness of OPTαGEL is shown in Fig. 7. Shock absorptivity under low impact acceleration (6400 m/s^2) was higher than that under high impact acceleration (27000 m/s^2) over a wide range of the hardness. In the case of lower 6400 m/s^2, the external impact was absorbed more than 50% by viscoelastic behavior of OPTαGEL. On the other hand, OPTαGEL series absorbed less than 50% when the impact acceleration was 27000 m/s^2. Deformation of each OPTαGEL in the high impact condition might be larger than that in the lower ones. It will probably need thicker OPTαGEL under the high impact condition to obtain enough high shock absorptivity.

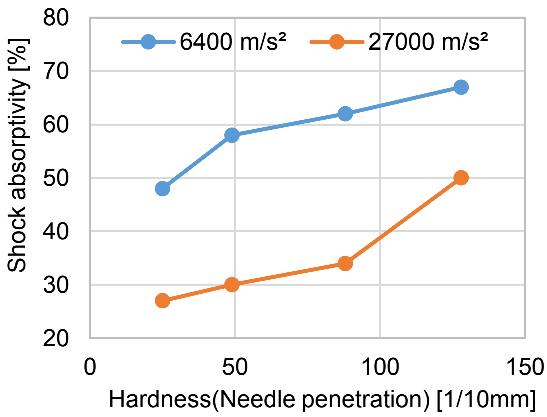

Fig. 7 Shock absorptivity depending on hardness of OPTαGEL.

As shown in Table 3, it was obvious that the cracking occurs easily when OPTαGEL was not used on the ultra-thin glass. And the cracking tended to occur at lower height when the ball point pen was used versus stainless ball. It was suggesting that the stress in case of the ball point pen was much higher than stainless ball since the diameter of the nib (0.7 mm) was smaller than the stainless ball (64 g). Although the ultra-thin glass did not crack by the 64 g stainless ball impact when OPTαGEL was installed. Furthermore, under the impact conditions of both the 230 g of stainless ball and the ball point pen, the results did not depend on the hardness, unlike its dependence on the shock absorptivity. When the drop impact is the major concern, "n90" of OPTαGEL is the best choice to protect the ultra-thin glass sample. "n130" might be deformed too largely to reach the ultra-thin glass before absorbing the impact fully. In any case, the result surely shows that OPTαGEL effectively absorbs the drop impact by releasing the stress in cooperation with the cover film. Therefore, it was suggested that OPTαGEL can improve mechanical durability of OLED lightning devices.

Table 3 Drop impact test result

Protection layer		Height glass cracked [cm]		
Cover film /Thickness [μm]	OPTαGEL Hardness /Thickness	Stainless ball 64 g	Stainless ball 230 g	Ballpoint pen
-	-	60~80	20~40	10
PET/100	-	90~100	60~80	20~50
PC/200	-	50~60	Passed	50~70
PET/100	n130/250	Passed	70	50~60
PC/200	n130/250	Passed	90	50~70
PC/200	n90/250	Passed	Passed	80
PC/200	n50/250	Passed	100	50~60
PC/200	n25/250	Passed	80~90	60

4 Application Products using This Technology

We have created unique products using this technology. Yamagata University is located in Yonezawa city, and one of the city's official mascot characters is "KANETAN". The model of "KANETAN" is Kagetsugu Naoe, who is one of the famous samurai. The family crest of “KANETAN” is "愛", which translates to "Love" in English. We made pencil cases and mouse shields etc. that light "愛" when the switch is pressed. Until now, OLED lighting using ultra-thin glass could not be used for products in such applications due to its insufficient mechanical durability. Since OPTαGEL has improved the durability of OLED lighting using ultra-thin glass, it can be used for such products.

4.1 Structure of OLED Lighting

The structure of the OLED lighting device is shown in Fig. 8. First, IZO was sputtered on ultra-thin glass and etched so that 32 mm square area or 10x8mm emitted. The insulator was printed by screen printing so that only the "愛" part was exposed on the IZO. By changing the shape of this insulator, any character can be displayed with light emission. Finally, the smoke film was laminated on the ultra-thin glass with OPTαGEL. The smoke film protected the reflected light from the cathode metal.

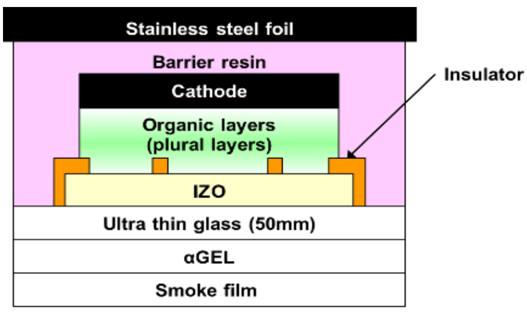

Fig. 8 The structure of the OLED lighting.

4.2 Final products

We introduce the pencil case, and the mouse shield as shown in Fig. 9 and 10. The mouse shield was lightly curved. All final products are equipped with flexible OLED lighting, a batterie and a switch. When the hidden switch was pressed, it was displayed as "愛".

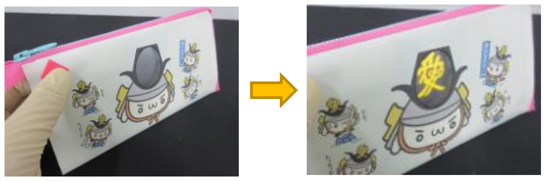

Fig. 9 Pencil case

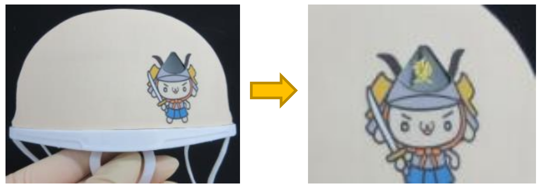

Fig. 10 Mouse shield

5 Conclusions

Mechanical durability of the flexible and long-life OLED lightning which is sealed up by fragile ultra-thin glass has been improved by the silicone gel, OPTαGEL. Furthermore, we have demonstrated some unique products installed flexible OLED lightning device with OPTαGEL as a protection layer. We will continue to test and collect some data for design of the protection layer, because it might change depending on the total product design, including rigidity, size, weight, and so on.

Acknowledgements

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