Effect of polymer particles on the light scattering properties of UV cured antiglare hard coating

Zheng Chang[1,2]，*Zhu Yang*[1,2]**，*Kangqing Deng*[1,2]，*Dongzhi Yuan*[1,2]，*Ping Xia*[1,2]
1.Hubei Institute of Aerospace Chemotechnology, XiangYang，Hubei 441003, China；
2.The Key Laboratory of Low Dimension Photoelectric Material and Devices of Hubei Province, XiangYang，Hubei 441003, China.

Abstract： The optical hard coating was treated with antiglare performance based on the preparation of UV curable coating liquids and hard coat film. Organic PMMA particles were selected as the antiglare particles. The parameter of the antiglare particle concentration, particle size, particle size distribution, refractive index difference with resin, coating thickness, and so on, which effect on the light scattering properties of UV cured antiglare hard coating were studied, respectively. The optical properties and surface morphology of the preparing antiglare hard coating were characterized by using transmittance Haze meter, gloss meter, and optical microscope, respectively. The results showed that, for adding the narrow distribution particles, Haze of antiglare hard coating would gradually increase and the gloss decrease as the particle size or particle content increased, while total transmission (TT) changed not obviously. Haze of the antiglare hard coating was lower when the refractive index of the liquid resin is similar to that of antiglare particles, and the gloss was higher. While the refractive index difference between the antiglare particles and resins is larger, Haze of the antiglare hard coating was higher, and the gloss was lower. Haze of antiglare hard coating is higher, and the gloss is lower when the coating thickness is relatively thin. TT of antiglare hard coating decreased, Haze first decreased and then increased, and the gloss was rising with the increase of the thickness of the coating. As for adding the wide distribution particles, the total transmission value of antiglare hard coating is lower, Haze is higher, and the gloss is lower.

Keywords： Antiglare ；Hard Coating；UV cured；PMMA

1. INTRODUCTION

LCD is mainly composed of a liquid crystal panel and backlight module (BLU). As LCD itself does not luminous, BLU is provided with sufficient brightness and uniform distribution of the light source, so that the LCD panel can display image. In the use of this kind of transmission type display, due to its internal light source will exit, thus may cause glaring phenomenon when the user look at the visual display. Another kind of circumstance is that the strong sunlight outdoor or indoor lighting projected onto the screen, which is also prone to produce reflection glare, and this glare will also makes users eye discomfort. So antiglare treatment is usually used on the surface of this kind of display, which diffusing the light emitted from the light source inside of the display, and reducing the reflection effect to alleviate visual fatigue caused by long time using.

** To whom correspondence should be addressed. E-mail:zhuyangah@gmail.com
Tel: +86-710-3219016; Fax: +86-710-3219111

Preparation method of antiglare film including dry and wet methods [1], which dry method depositing material onto the screen to form film formed by vacuum evaporation, vapor deposition (CVD, PVD), sputtering method. Wet coating is coating the antiglare material on a film substrate, drying and curing to form an antiglare film. Optical grade PET films were widely applied in the field of liquid crystal display (LCD) in recent years because they had excellent property, such as high total transmission (TT), low Haze, high gloss, non-yellowing, good adherent strength, good flatness, no shading lines, resistance to high temperature and ultraviolet radiation, high tensile strength, excellent stiffness, anti-burning bifida, not easily broken, etc. [2]. Many kinds of functional optical thin films can be prepared when the surface of PET film was coated with various functional coating [3-4]. Among of them, hard coat film can be prepared by wet precision coating UV curing coating [5] on the surface of PET film, which possessing a wide range of applications [6-7]. UV curing coating is an environment-friendly and energy-saving coating, which is developed at sixties of the 20 century. Due to UV curing system has higher cross-linking density, thus the components of the coating can be adjusted to obtain the required performance [8-9], and has good wetting and dispersing properties for the nanometer inorganic metal oxides and organic polymer particles. Higher cross-linking density can be formed after the UV irradiation, and producing transparent, anti-scratch performance film, which are widely used for preparation the hard coat film. In the preparation hard coating, if the organic or inorganic particles are used, by adjusting the thickness of the coating film to make the particles exposing on the surface of the film partly, thus can form concave-convex effect of the antiglare hard coat film [10-13]. This paper studies the effect of organic polymethyl methacrylate (PMMA) particles on the light scattering properties of UV cured antiglare hard coating, and Haze, total transmission (TT), and gloss were used to characterize the light scattering properties.

2. EXPERIMENTAL

2.1 Materials

Optical grade polyester (PET) film with thickness of 100 microns, was supplied by SKC Corporation (Korea). UV curing coating liquids was prepared by mixing polyurethane acrylate resin and acrylate monomers and photoinitiator. Organic particles are PMMA particles, micron grade, was supplied by Sekisui Co. Ltd. (Japan). The dilution solvents are industrial grade, produced in china.

2.2 Measurements

Pilot Coater with heat drying unit and UV curing unit, was supplied by AMO Corporation (Korea), used for preparation antiglare hard coating through wet coating method.

DAWN EOS Laser light scattering instrument，was supplied by Wyatt Corporation (USA), used for test particle size and particle size distribution.

XYL-3400 continuous zoom stereo microscope, was supplied by Shanghai Precision Instrument Co., Ltd., used for observe the surface morphology of the antiglare hard coating, and the image acquisition software is Scope photo Ver.3.0.

NDH-5000 Transmittance Haze meter was supplied by Nippon Denshoku Kogyo Co., Ltd., used for test TT and Haze of the antiglare hard coating according to ASTM D1003 Standard.

JFL-BZ 20°、60°、85° Intelligent Gloss Meter, Tianjin Jin Fulun Technology Co., Ltd.，
60° gloss test method according to GB9754-88 Standard.

2.3 Preparation coating liquids of the antiglare coating

Dispersing wetting agent and a certain proportion of PMMA particles were added into the diluents with stirring, and then added the UV curing coating liquids self-made, mixing uniformity to obtain coating liquids of the antiglare coating.

2.4 Preparation of the UV cured antiglare hard coating through wet precision coating

By using Pilot Coater, optical grade PET film was transferred from the unwinding unit to the coating unit, where it was coated with a certain thickness of different formula antiglare coating through mesh roller, and then passed through the heat drying unit and the UV curing unit to form cured coating, finally was winded to produce the antiglare hard coat film.

3. RESULTS AND DISCUSSION

3.1 Effect of particles size on the light scattering properties of UV cured antiglare hard coating

Because particles exists in the UV curing coating liquids, thus the surface of the cured hard coating forming micro concave-convex structure, and the size of the particles affects the surface micro concavo-convex directly. PMMA particles with different particle size were used to mix with UV curing coating liquids respectively, and the particle/resin ratio is fixed. The property of the preparing antiglare hard coating measured was shown as in Table 1 (Formulation No 3, 4 and 5 used narrow distribution particles, and Formulation No 2 used wide distribution particles).

Table 1 Effect of particles size on the light scattering properties of UV cured antiglare hard coating

Formulation No	TT（%）	Haze（%）	Coating thickness（μm）	60° Gloss（%）
1（UV curing coating liquids）	91.71	0.83	4~5	170.2
2（Add size of 2μm particles）	90.42	21.60	5~6	36.6
3（Add size of 3μm particles）	91.69	11.23	5~6	94.7
4（Add size of 5μm particles）	91.42	12.53	5~6	69.7
5（Add size of 8μm particles）	91.24	64.78	7~8	11.0

From Table 1, it can be seen that, except for Formulation No 2, as the particle size become larger, Haze of the antiglare hard coating increased, the gloss gradually decreased, and TT changed little. This is mainly due to, with the increase of narrow distribution particle size, the rough degree of the coating surface caused by particle gradually increased. Particles in the Formulation No 2 are wide distribution particles, thus creating larger uneven on the surface of the coating, resulting in lower gloss and higher

Haze. The microstructure of the antiglare coating preparation with different diameter particles was observed by optical microscope, which was shown as in Figure 1.

From Figure 1, it can be seen that, the surface of Formula Number 2 coating is uneven. Although the average diameter of the particles is only 2 microns, but the particle size distribution is wider, and the size is not uniform, thus the surface structure is not smooth. 3 micron diameter and 5 micron diameter of the narrow distribution particles dispersed in the coating uniformly. 8 micron diameter of the narrow distribution particles is bigger than the thickness of the coating, thus scattering effect of the refraction light increased, and Haze increased. If the average size of the particles used for preparation the antiglare hard coating is too small, the surface can not form the concave-convex shape enough, thus cannot give glare prevention function enough. On the other side, if the average size is too big, it will make the difference of the surface concave-convex too big, bringing foreign body sensation on the appearance of the coating, and the scattering of the reflecting light will enhance, thus easy to produce whitening phenomenon.

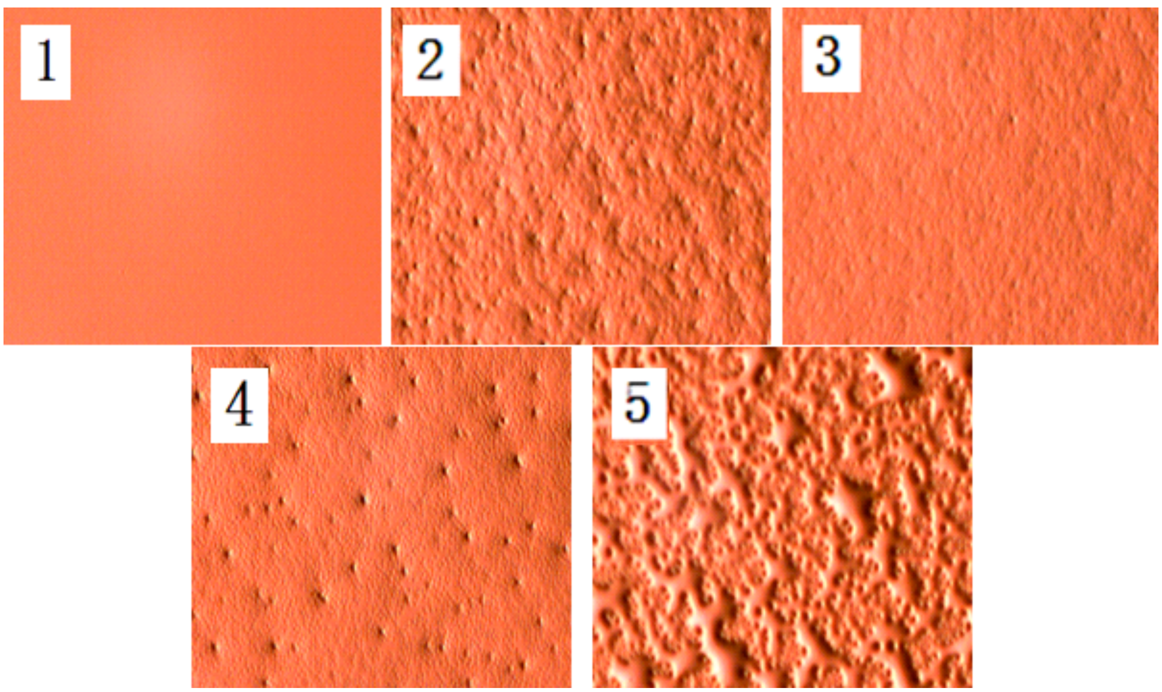


Figure 1 The optical microscope photos of the microstructure of the antiglare coating preparation with different diameter particles

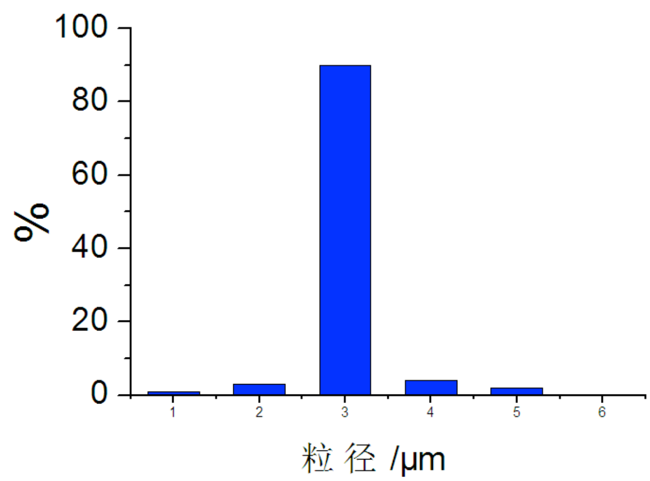
3.2 Effect of particles size distribution on the light scattering properties of UV cured antiglare hard coating

PMMA particles of different particle size distribution with same particle average size were used to mix with UV curing coating liquids respectively, and the particle/resin ratio is fixed. The property of the preparing antiglare coating measured was shown as in Table 2 (MH and MB particle refers to wide distribution particle, and there is a very small difference of particle size distribution coefficient).

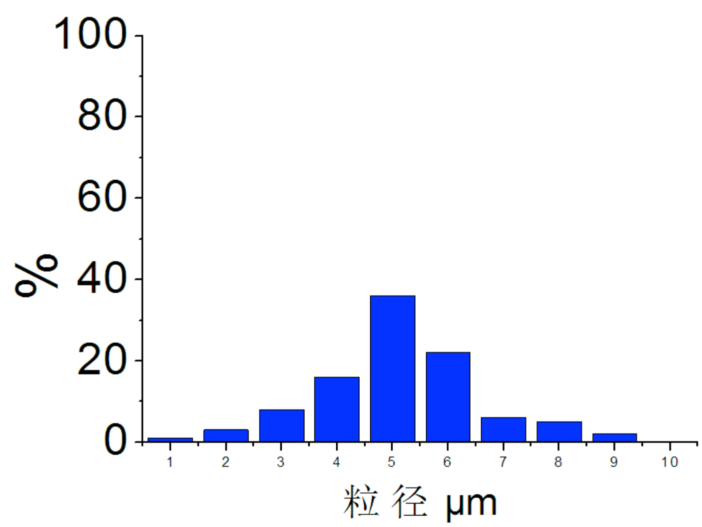
The size distribution of the narrow distribution and wide distribution PMMA particles was measure by Laser light scattering instrument, which was shown as in Figure 2, and the micro morphology of narrow distribution and wide distribution particles was shown as in Figure 3.

Table 2 Effect of particles size distribution on the light scattering properties of UV cured antiglare hard coating

Particle types	TT（%）	Haze（%）	Coating thickness（μm）	60° Gloss（%）
1（MH: Wide distribution ）	90.96	20.60	6~7	57.2
2（MB: Wide distribution）	90.83	18.81	6~7	50.7
3（Narrow Wide distribution）	91.42	12.53	5~6	69.7



（a） **Narrow distribution particles（Size of 5μm）**



（b） **Wide distribution particles（Size of 5μm）**

Figure 2 Size distribution of PMMA particles:（a）Narrow distribution particles(Size of 5μm),（b）Wide distribution particles（Size of 5μm）

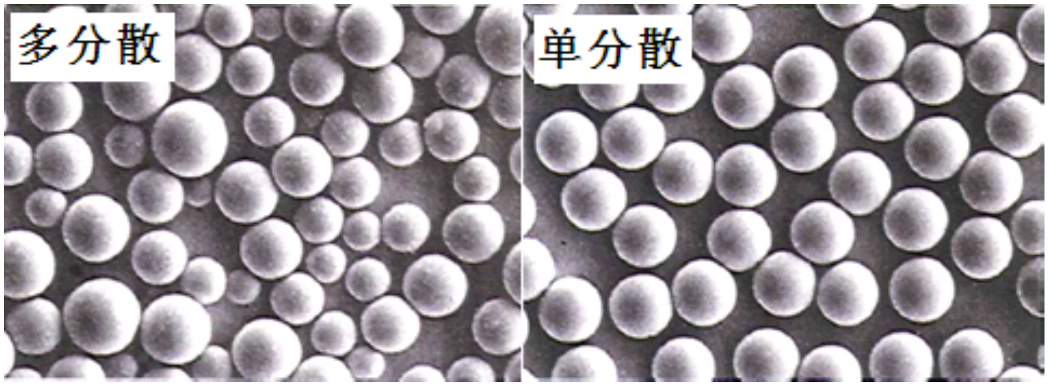


Figure3 The micro morphology of narrow distribution and wide distribution particles

From Table 2, it can be seen that, under the condition of the same particle content, the antiglare hard coating formed from wide distribution particles possess lower TT, higher Haze and lower gloss. Three kinds of coating microstructure were observed by optical microscope, which was shown as in Figure 3.

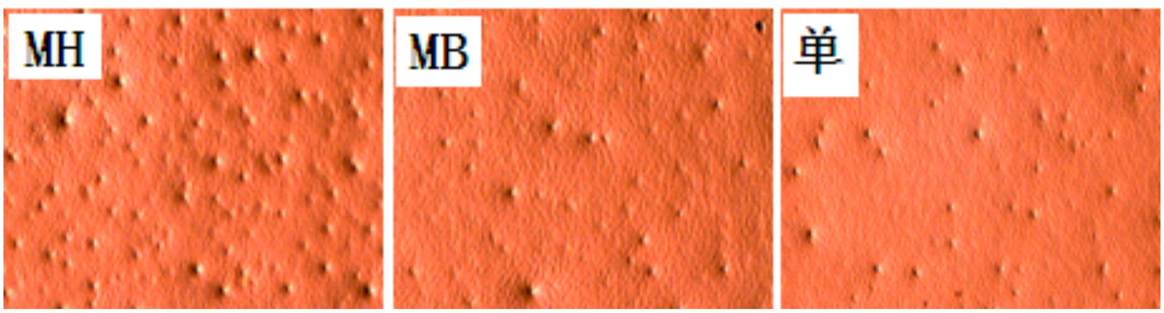


Figure 3 Effect of particles size distribution on the light scattering properties of UV cured antiglare hard coating（The optical microscope photos）

From Figure 3, it can be seen that, as wide distribution particles dispersed in the coating creating larger fine concave-convex structure on the surface the coating, thus affected of scattering and refraction of light in the coating, and also affected the thickness of the coating. So, the coating thickness containing wide distribution particles increased slightly, and the rugged surface increased significantly, and the gloss and TT is lower, Haze is higher.

3.3 Effect of particles content on the light scattering properties of UV cured antiglare hard coating

Narrow distribution particles were selected for study. Different content of particles were mixed with UV curing coating liquids, and the properties of the preparing antiglare coating measured were shown as in Table 3.

Table 3 Effect of particles content on the light scattering properties of UV cured antiglare hard coating

Particles content	TT（%）	Haze（%）	Coating thickness（μm）	60° Gloss（%）
1（1%）	91.73	2.08	5~6	154.6
2（10%）	91.62	5.83	5~6	115.1
3（15%）	91.42	12.53	5~6	69.7
4（20%）	91.33	16.06	6~7	55.2

From Table 3, it can be seen that, as particles content increased, TT of the antiglare coating decreased slightly, Haze increased obviously, and the surface gloss decreased obviously. When the particle content is less, the surface of the antiglare coating is smooth, the gloss is high, thus can not play the effect of antiglare. As the particle content increased, the role of light scattering and refraction in the coating is obviously, and thus Haze increased. The surface coating is more rugged, reduced gloss value. When the concave-convex of the surface of the antiglare coating to a certain extent, it will cause the coating surface white fuzzy phenomenon, thus cause visual effects decline.

Four kinds of coating microstructure were observed by optical microscope, which was shown as in Figure 4.

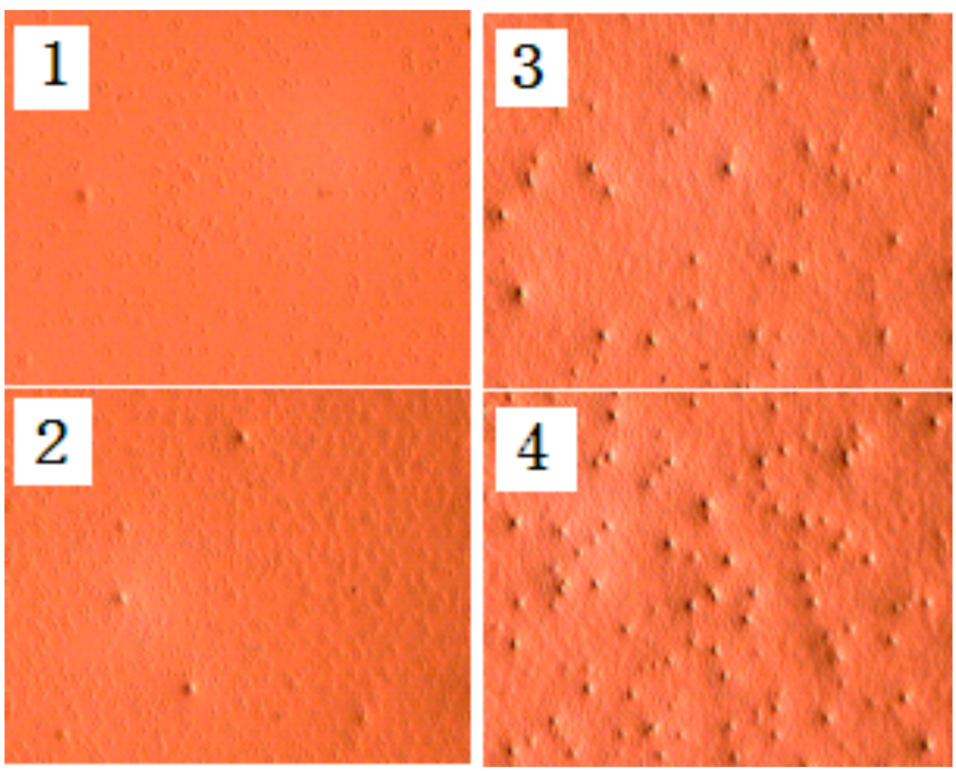


Figure 4 Effect of particles content on the light scattering properties of UV cured antiglare hard coating（The optical microscope photos）

From Figure 4, it can be seen that, as particles content increased, the number of particles per unit area in the coating film increased, the role of light refraction in the internally coating becomes strong, and the role of light scattering in the surface of the coating also becomes strong, thus Haze change, and the antiglare effect increased. With respect to the particle of the antiglare coating, if the particle content is too low, it will be difficult to obtain good antiglare properties. On the other hand, if the particle content is too high, sometimes the hardness of the antiglare hard coat film will reduce, and the scratch resistance property will decrease.

3.4 Effect of the refractive index difference between the antiglare particles and resins on the light scattering properties of UV cured antiglare hard coating

Narrow distribution particles were selected for study. Resins with different refractive index (RI) were mixed with PMMA particles, and the properties of the preparing antiglare coating measured were shown as in Table 4. The RI of PMMA particles is similar with No3 Resin.

Table 4 Effect of the refractive index difference between the antiglare particles and resins on the light scattering properties of UV cured antiglare hard coating

Resin with different RI	TT（%）	Haze（%）	Coating thickness（μm）	60° Gloss（%）
1（RI=1.40）	90.47	32.90	4~6	65.5
2（RI=1.45）	90.43	28.07	5~6	69.7
3（RI=1.50）	91.67	16.17	5~6	78.5
4（RI=1.55）	92.60	43.47	5~6	68.3
5（RI=1.60）	91.76	47.71	5~6	62.8

From Table 4, it can be seen that, Haze of the antiglare hard coating was lower when the refractive index of the liquid resin is similar to that of antiglare particles, and the gloss was higher. While the refractive index difference between the antiglare particles and resins is larger, Haze of the antiglare hard coating was higher, and the gloss was lower. The total transmission (TT) changed not obviously.

Five kinds of coating microstructure were observed by optical microscope, which was shown as in Figure 5.

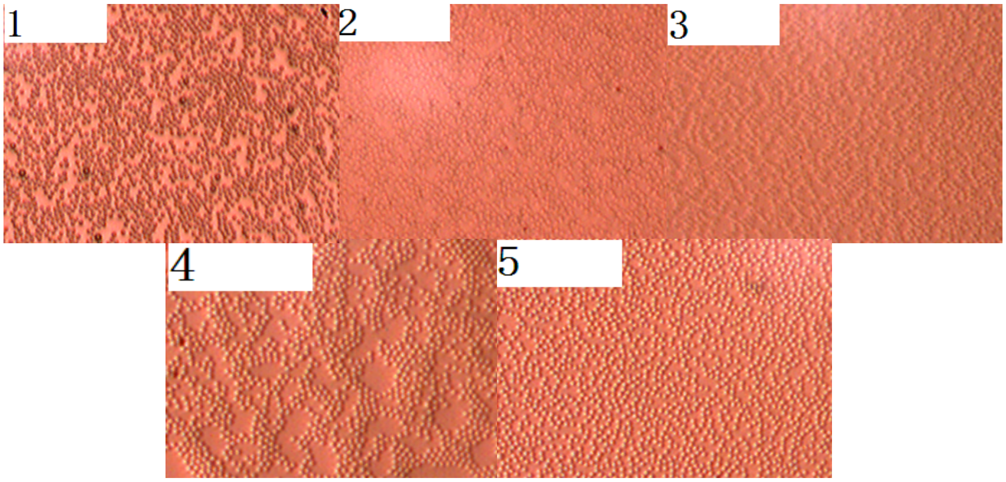


Figure 5 Effect of the refractive index difference between the antiglare particles and resins on the light scattering properties of UV cured antiglare hard coating（The optical microscope photos）

Since the particles contents were same for all the formula, and the film forming were also same, thus the content of particles per unit area for all the cured coating were the same. From Figure 5, it can be seen that, due to the performance of the resin, resulting in slightly different apparent coating. When the refractive index of the liquid resin is similar to that of antiglare particles, whitening phenomenon of the cured antiglare hard coating was least, and possessed better antiglare performance.

3.5 Effect of coating thickness on the light scattering properties of UV cured antiglare hard coating

Antiglare coating was prepared through precision coating by Picot Coater, screen roller with different mesh size were used to prepare different coating thickness (after curing) for the same formulation of the coating liquids, and narrow distribution particles were selected for study. Effect of coating thickness on the properties of the antiglare hard coat film was tested, and the results were shown as in Table 4.

Table 4 Effect of coating thickness on the light scattering properties of UV cured antiglare hard coating

No	TT（%）	Haze（%）	Coating thickness（μm）	60° Gloss（%）
1	92.47	71.9	3~4	10.4
2	91.42	12.53	5~6	69.7
3	90.83	21.96	7~8	105.7
4	91.20	32.58	13~14	125.9

From Table 4, it can be seen that, the optical properties of the antiglare hard coating vary greatly when the coating thickness is different. In the Formulation No 1, the coating thickness is lowest, nevertheless Haze is highest, and the gloss is lowest. With the increase of the thickness of the coating, TT of the antiglare hard coat film decreased, Haze decreased firstly and then increased. The coating microstructure was observed by optical microscope, which was shown as in Figure 5.

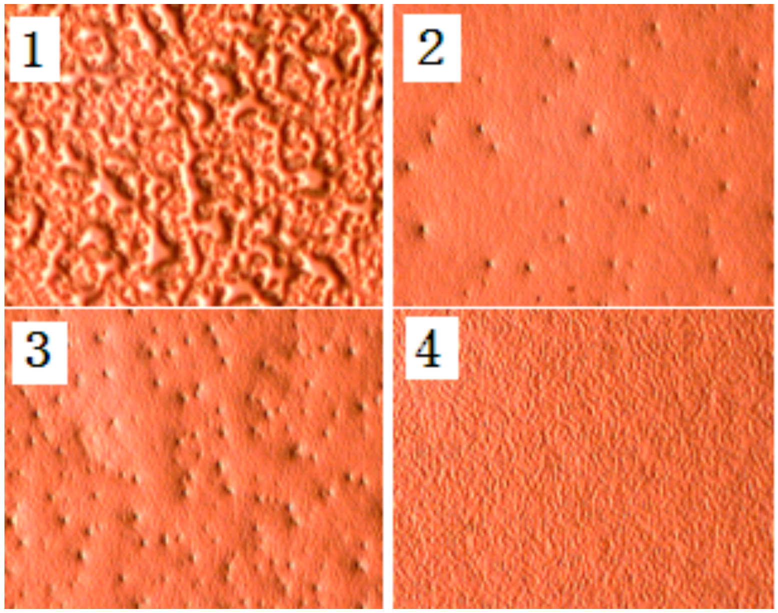


Figure 5 The optical microscope photos of the antiglare coating microstructure preparation with different coating thickness

From Figure 4, it can be seen that, when the coating thickness is relatively thin, most of the particles were exposed on the outside surface coating of the antiglare hard coat film, and the surface of the coating was uneven seriously, which strengthened the light refraction and scattering ability, thus Haze was larger, and gloss was lower. With the increase of the coating thickness, the particles of the antiglare hard coat film were buried in the coating gradually, the convex-concave effect of the coating was weakened, thus Haze increased slightly. When most of the particles of the antiglare hard coat film were buried in the inner of the coating, the coating surface is smooth, the gloss increases significantly, and the antiglare effect is reduced greatly.

4. CONCLUSIOM

Haze of the antiglare hard coat film would gradually increase and the gloss would decrease as the particle size or particle content increased, while TT would change not obviously. Haze of the antiglare hard coat film is higher, and the gloss is lower when the coating thickness is relatively thin. Haze of the antiglare hard coating was higher, and the gloss was lower, when the refractive index difference between the antiglare particles and resins is larger. TT of the antiglare hard coat film would decrease, Haze would decrease firstly and then increased, and the gloss would rise with the increase of the thickness of the coating. As for adding the wide distribution particles, TT of the antiglare hard coat film is lower, Haze is higher, and the gloss is lower.

References

[1] Wu, C. C.; Yang, H.; Yuan, J.; et al. Materials Science & Engineering，**2002**, 20（1）：133-136.

[2] Yuan, D. Z.; Deng, K. Q.; Yang, Z. Chemistry and Adhesion，**2012**，34（2）：59-64.

[3] Wang, X. J.; Wang, Q. W.; Bai, G. L; et al. Information Recording Materials，**2011**, 12(5)：42-51.

[4] Li, L.; Ma, T. L. Information Recording Materials，**2008**, 9(1)：40-50.

[5] Xie, Y. F. Information Recording Materials, **2010**, 11(1), 28-37.

[6] Yang, Z.; Deng, K. Q. The 2nd International Forum on Radiation Curing Industry Development (IFRCID-2012)，Hefei, China, **2012**, 124-134.

[7] Yang, Z.; Deng, K. Q.; Zhang, H. Y., et al.，CN 102236113 A, **2011**-11-09.

[8] Nie, J.; Xiao, M. Beijing：Chemical Industry Press，**2009**.

[9] Yang, J. W.; Zeng, Z. H.; Chen, Y. L. Beijing：Chemical Industry Press，**2008**.

[10] Deng, K. Q.; Yang, Z.; Chang, Z.; et al. CN201210314648.7，**2012**-08-30.

[11] Liu, B. T.; Teng, Y. T.; Lee, R. H.; et al. Colloids and Surfaces A: Physicochemical and Engineering Aspects, **2011**, (389) 138– 143.

[12] Tomoyuki, M. US Patent 6,217,176, **2001**-04-17.

[13] Hiroko, S.;, Shinjukju K. US Patent 6,693,140, 2004-02-24.