Advanced Reflectionless Technology for Reflected Glare Reduction

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ABSTRACT

In this paper, we propose the new surface treatment technology (A.R.T.) that can increase ACR and GKR significantly under complex illumination. A subjective experiment of visual performance is executed that the difference of subjective rating results of new and commonly surface treatments of legibility and comfort are significant under specular illumination.

1 INTRODUCTION

Display applications are increased and used everywhere nowadays. Most of consumers only pay attention to the specifications of display under the darkroom. Actually, display is operated under the complex illumination in real life, ambient picture quality and visual performances are important for users.

Reflected glare is one of the most disturbing problems while we are watching display devices. To reduce the effects of reflected glare, several surface treatment technologies are applied on displays, for example, Anti-glare film (AG) and Anti-reflection film (AR). In previous studies [1], specular reflection included in the hybrid illumination is the main factor to affect the ambient picture quality and visual performance. Only applying AG or AR surface treatments can't deal with specular reflection well.

In this paper, we propose a new surface treatment, called "Advanced Reflectionless Technology (A.R.T.)", which is included two features: a high roughness surface with designed structure to change the directions of reflection light, and a special coating technology to reduce the amount of reflection light. Comparisons of different surface treatment specification are listed in Table 1, ρ of A.R.T. is similar with ρ of AR, it could present good PQ performance under diffuse illumination. The specular reflectance ξ of A.R.T. is 10 times lower than ξ of AG & AR, and it could reduce the specular reflection effectively.

	ρ	ξ
AG	**5.4%**	**0.5%**
AR	**1.6%**	**0.9%**
A.R.T.	**< 2%**	**< 0.05%**

Table 1. Reflectance comparison

Compare with different surface treatment of reflectance

Three ambient picture quality indices are introduced in this paper. Gloss value is a practical index to quantify the specular reflection by an easy and quick measurement. Ambient contrast ration (ACR) has been introduced in several international standards and used widely in many researches. Gamut keeping ratio (GKR) is a new proposed method to compare with the color performance in dark and ambient environments.

Subjective tests of visual performance which included legibility and comfort are executed with different surface treatments under different illuminations, the test results shows that A.R.T. could keep better visual performance and higher score in the tests.

2 Ambient picture quality indices of different surface treatments

2.1 Gloss value

Gloss measurement is a practical way to get a specular reflection value. It could help us quickly compare specular reflection property of different surface treatments which shown in Table 2. (Data were measured by BYK 4376).

	20°	60°
AG	**16.0**	**52.5**
AR	**18.1**	**33.2**
A.R.T.	**0.4**	**1.9**
A4 paper	**1.1**	**3.9**

Table 2. Gloss value comparison

Compare with different surface treatment of gloss value

2.2 ACR

Refer to IDMS standard [2] and reference paper [1], the hybrid ambient settings combined diffuse and specular illumination. The ambient contrast ratio follows formula (1).

$$\mathrm{ACR} = \frac{\mathrm{L_W} + \rho_{\mathrm{SI}}\mathrm{E}_{hemi}/\pi + \xi_{\mathrm{S}}L_s}{\mathrm{L_K} + \rho_{\mathrm{SI}}\mathrm{E}_{hemi}/\pi + \xi_{\mathrm{S}}L_s} = \frac{L_{\mathrm{W}amb}}{L_{\mathrm{K}amb}} \qquad (1)$$

The ACR results of three kinds of surface treatment are shown in Fig. 1. The ACR of A.R.T. was dramatically better than AG and AR under D+S illumination.

Four hybrid ambient light settings (diffuse + specular (a) ~ (d)) were applied to simulate the real environment conditions that are the same with in Table 1 of reference paper [1]. A specular illumination aperture size was a 1cm*1cm. Display peak luminance was 250nits.

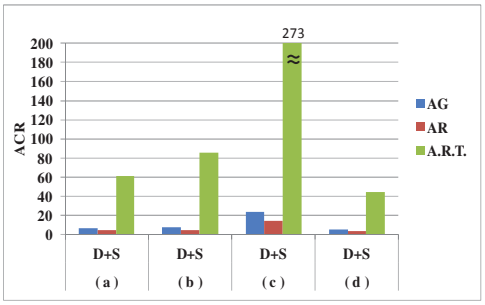


Fig. 1 ACR comparison

The ACR results of three kinds of surface treatment under hybrid illumination

2.3 GKR

The surface treatment reflection spectrum was measured. Therefore spectrum of color Q display pattern under hybrid ambient environment can follows formula (2).

$$L_{Qamb}(\lambda) = \mathrm{L_Q}(\lambda) + \rho_{\mathrm{SI}}(\lambda)\mathrm{E}_{hemi}(\lambda)/\pi + \xi_{\mathrm{S}}(\lambda)L_s(\lambda) \quad (2)$$

Where $L_{Qamb}(\lambda)$ is the total ambient spectral radiance.

The ambient chromaticity of a display at a given color state under defined illumination conditions is determined by its equivalent ambient tristimulus values [2]. The values follow formula (3).

$$\begin{aligned} \mathrm{X}_{Qamb} &= 683\int_{\lambda} \mathrm{L}_{Qamb}(\lambda)\bar{\mathrm{x}}(\lambda)\mathrm{d}\lambda \\ \mathrm{Y}_{Qamb} &= 683\int_{\lambda} \mathrm{L}_{Qamb}(\lambda)\bar{\mathrm{y}}(\lambda)\mathrm{d}\lambda \\ \mathrm{Z}_{Qamb} &= 683\int_{\lambda} \mathrm{L}_{Qamb}(\lambda)\bar{\mathrm{z}}(\lambda)\mathrm{d}\lambda \end{aligned} \quad (3)$$

The ambient 1931 CIE x and y chromaticity coordinates are then given by

$$\begin{aligned} \mathrm{x} &= \frac{\mathrm{X}_{\mathrm{Qamb}}}{\mathrm{X}_{\mathrm{Qamb}} + \mathrm{Y}_{\mathrm{Qamb}} + \mathrm{Z}_{\mathrm{Qamb}}} \\ \mathrm{y} &= \frac{\mathrm{Y}_{\mathrm{Qamb}}}{\mathrm{X}_{\mathrm{Qamb}} + \mathrm{Y}_{\mathrm{Qamb}} + \mathrm{Z}_{\mathrm{Qamb}}} \end{aligned} \quad (4)$$

When Q is R/G/B display pattern, we gets the gamut of display under ambient illumination (G_{amb}). When in the dark room, formula (2) can be modified to:

$$L_{Qdark}(\lambda) = \mathrm{L_Q}(\lambda) \quad (5)$$

Calculated by formula (3) and (4), we gets the gamut of display under dark room (G_{dark}) that schematic is shown in Fig. 2. The gamut keeping ratio can follows formula (6).

$$\mathrm{GKR} = \frac{\mathrm{G}_{\mathrm{amb}}}{\mathrm{G}_{\mathrm{dark}}} \times 100\% \quad (6)$$

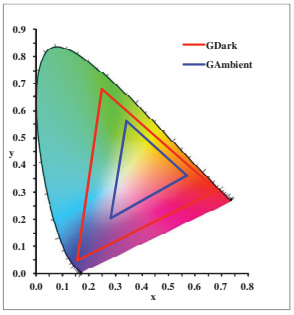


Fig. 2 schematic diagram of GKR

The gamut of display under ambient and dark environment

The GKR results of three kinds of surface treatment under the hybrid illuminations are shown in Fig. 3. The GKR of A.R.T. was more batter than others surface treatment films. Under any illumination conditions, the GKR of A.R.T. was still keep over 90%.

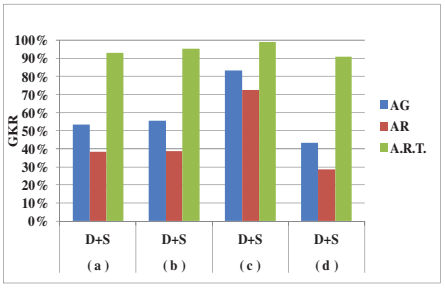


Fig. 3 GKR comparison

The GKR results of three kinds of surface treatment under hybrid illumination

According to the ACR and GKR results, A.R.T. could effectively reduce the effects of reflected glare and improve picture quality.

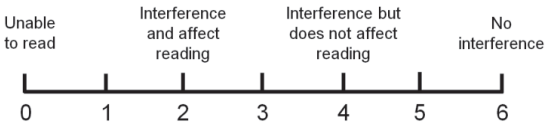
3 Subjective experiment

3.1 Experiment condition setting

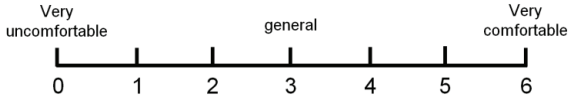
A subjective experiment was designed to check the visual performance of reflected glare disturbance. Based on before research, experiment environment, illumination, lighting, display, texts pattern, all settings were the same of reference paper [1]. Participant was asked to observe the contents on display under different illuminations, and to answer the questionnaires for rating the visual quality which included “Legibility” and “Comfort”.

There are two questionnaires using a 7 category-point scale:

1. **Legibility** : The level of interference of the light source on reading the text



2. **Comfort** (including overall picture feeling)



3.2 Discussion

ACR of A.R.T. results compare with commonly surface treatment films under diffuse illuminations are plotted in Fig. 4(a). With the ambient illumination increase, ACR reduces gradually, result of A.R.T. and AR are similarly.

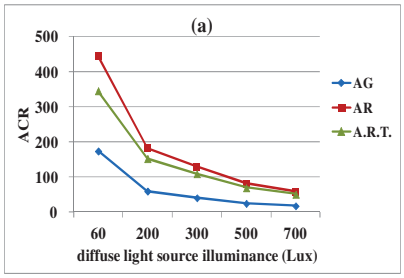


Fig. 4 ACR comparison

Compare with ACR results under diffuse illuminations

In the results of subjective experiment, the legibility and comfort average results plot in Fig. 5(a) and 5(b). With the luminance increases, A.R.T. has similar result with common films which legibility rating can be maintained above 4 and comfort rating above 3. According to statistical results of three surface treatments, P-Value > 0.05, it means that the differences of subjective rating on legibility and comfort of all surface conditions are not significant under diffuse illumination.

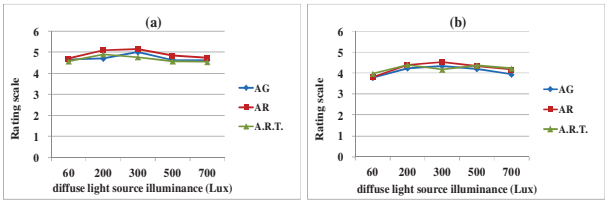


Fig. 5 Results of subjective test

(a) Legibility rating (b) Comfort rating under different diffuse light source conditions.

ACR results under five specular illuminations with aperture size SS plot in Fig. 6(a). With the ambient illumination increases, ACR reduces gradually but A.R.T. significant higher much more than others surface treatments.

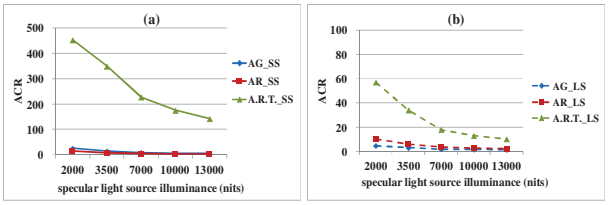


Fig. 6 Results of ACR with different aperture size

(a) Small Size (c) Large Size under different specular light source conditions.

In the results of subjective experiment, the legibility and comfort average results plot in Fig. 7(a) and 7(b). With the luminance increases, Legibility rating can be maintained above 4 and comfort rating above 3 on AG but only A.R.T. which legibility rating can be stable above 5 and comfort rating close 5. According to statistical results, the differences of subjective rating on legibility and comfort of A.R.T. with AR or AG are significant under specular illumination.

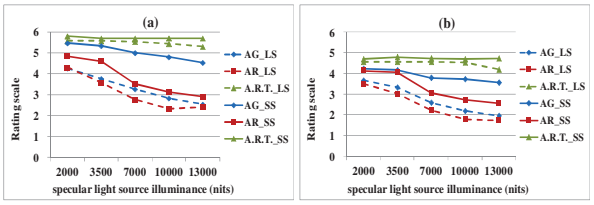


Fig. 7 Results of subjective test

(a) Legibility rating (b) Comfort rating under different specular light source conditions.

The other aperture condition is large size (LS), to simulate the larger light sources, such as window / flat lighting, ACR results plot in Fig. 6(b). ACR drops more significantly, but A.R.T. still higher than others. In the results of subjective experiment under high luminance lighting, AG and AR below 3 but A.R.T. of legibility rating can still keep above 5 and comfort rating above 4. We compare the rating results of 2 aperture size illuminations which is little impact for A.R.T.

Based on the above conclusions, A.R.T. is to show significantly superiority to reduce reflected glare better than others surface treatments under different specular illumination conditions that include lighting level and aperture size of illumination. This means that picture quality and visual performance will be improved.

4 Conclusion

Reflected glare is a significant factor to affect the ambient picture quality, especially on the specular reflection. According to the ACR results, A.R.T. can effectively reduce mirror side of reflected glare and greatly improved ACR value. GKR of A.R.T. can keep over 90% under different illumination conditions in this paper. The GKR index is important for indicating that the display color property is retained under ambient environment.

In results of subjective experiment, Rating of A.R.T. is similar with commonly films under diffuse illumination but which can keep higher level under different specular illumination conditions. According to the above conclusion, A.R.T. surface treatment can effectively improve ambient picture quality and visual performance evaluation under hybrid illumination, especially include strong specular illumination.

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