Image Permanence of photographic prints under LED lighting

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Abstract

LED (Light Emitting Diode) lighting has been widely used as a major light source to illuminate photographic prints. But it is not clear how aggressive LED lighting affects to image stability of prints. The light stability tests were carried out using some commercially available white LED lamps and fading behavior was compared to the standardized xenon light testing which simulates indirect sunlight indoor. It was clarified that fading under LED lighting is less than xenon lighting but it correlates well to the xenon testing in the order of prints in light stability.

Background and purpose

LED (Light Emitting Diode) lighting has been improved in its efficiency and production costs over recent years. Now it is widely used as indoor illumination in consumer homes, offices and commercial buildings. So it is often the case that photographic prints are displayed under LED lighting.

Photographic prints tend to fade under light exposure during time. Stability of prints varies depending on the type of printing technologies and materials. It is also affected by the characteristics of the light source. But fading behavior under LED lighting is not well known, because the history of LED lighting is not so long.

Acceleration light exposure testing at higher illuminance is executed to evaluate the fading characteristics of the prints. ISO 18937 stipulates the method of acceleration tests using xenon light source with ultra-violet (UV) cut filter which simulate typical indoor lighting. There is no testing standard for LED illumination and no LED testing equipment which is commercially available for photographic prints.

The purpose of this research is to clarify the fading behaviors of photographic prints under LED lighting and also the relationship between the results of the ISO method using xenon lighting and fading behaviors under recent LED lighting.

Light stability testing

The light stability tests were carried out using UV filtered xenon light and some commercially available LED lamps, which have different colour temperature. A wide range of photographic prints were selected and tested. The fading behaviors were compared between xenon and LED lamps, and between the LED lamps.

Experimental apparatus

For xenon light exposure, commercially available testing equipment "XL75" of Suga Test Instruments Japan was used. UV filter (half cut wavelength is 370nm) was inserted between light source and samples. These settings are stipulated in ISO 18937 for simulating indoor daylight typical home display.

For LED light exposure, testing equipment was constructed with LED lamps and print sample holders. Schematic view of the equipment is shown in Figure 1. Straight tube lamps were set in parallel to illuminate uniformly the entire surface of sample specimens. The four sides of the equipment are kept open to allow air flow of the laboratory. The condition of the room was controlled within 23 ±2 °C and 50 ±5 %RH.

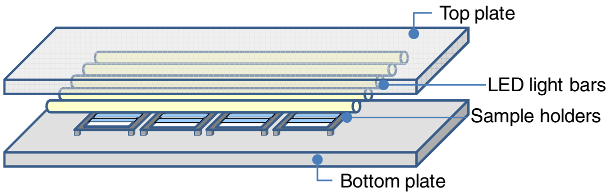

Figure 1. *Schematic view of LED exposure testing*

Three types of commercially available LED lamp, including "Daylight type", "White type" and "Warm white type", were tested. They are generally used in various indoor situations. The Model name and color temperature (CT) are shown in Table 1.

Table 1: LED light source for testing

Type	CT	Model
Daylight	6500K	Panasonic LDL40SD1923
White	4000K	Panasonic LDL40SW1923
Warm white	3500K	DN Lighting SCF-LED1139WW-APD

Comparison of the spectrum is shown in Figure 2. LED lamps have the specific peak around 450 nm, which is originated from blue LED chip. Besides there exist broad peaks between 550nm and 600 nm, which are originated from phosphors. These types of LED are the most popular for indoor illumination in the world. It is generally said that color temperature of white LED is controlled with the sort and the amount of the phosphors.

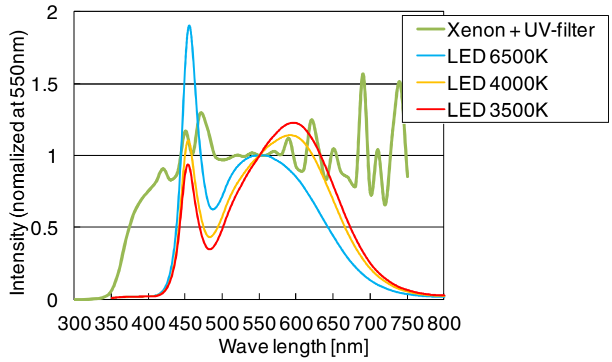

Figure 2. *Comparison of the spectrum of light sources for testing*

Testing conditions

Xenon light exposure testing was performed according to the stipulation of "Simulated indoor light typical home display" in ISO 18937. The light intensity was set at 80klx on the sample surface. Chamber air was conditioned to 25°C, 50%RH and black panel temperature was controlled to 35°C

For LED light exposure testing, the distance between the lamps and the surface of prints was adjusted to 30 mm where validation in light exposure is within the range of 3% over whole sample area. Data of light intensity (illuminance) and temperature of the print surface are shown in Table 2.

Table 2: Illuminance and temperature of print surface

Light source	Illumi-nance	Surface temperature of samples		
		white	gray(D=0.5)	black
LED 6500K	35klx	28.7	30.5	31.5
LED 4000K	35klx	-	-	-
LED 3500K	70klx	32.9	35.9	36.8

Print samples

Twelve commercially available photographic prints for consumer and commercial use, including inkjet (dye, pigment), electrophotography (solid, liquid), silver halide and D2T2 were prepared. Each sample was named alphabetically from "Sample A" to "Sample L". 22 colour patches were printed as shown in Figure 3. Printed sheets were cut to the strips with the size of 22mm x 122mm. Three of 22 colour patches were identical grey ones with optical density of 1.0 for checking locality of fading.

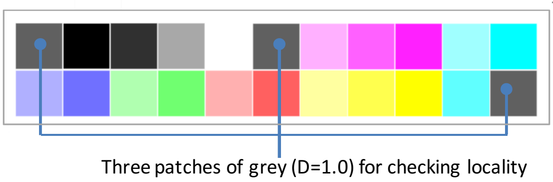

Figure 3. *A print sample for light stability testing*

Evaluation method for image stability

Fading behavior of each sample was evaluated with the averaged colour difference ΔE_{76} which is reported to correlate well to the human perception [2]. The chromaticity of each colour patch was measured before and after light exposure of several durations. The measuring condition M0 described in ISO 13655 [3] was applied. The geometry was 45°/0° with a 2° observer for detector, and the illuminant was CIE illuminant D50. The colour differences, ΔE, for each initial and each faded sample after light exposure were calculated. For ΔE, the values CIE 1976 ΔE_{76} (ΔE^*_{ab}) stipulated in ISO 11664-4 [4] were calculated. The ΔE_{76} values of three identical grey patches were averaged. Finally the averaged colour difference ΔE_{76} was calculated by averaging the value ΔE_{76} of twenty colours of the sample.

Results and consideration

The profiles of the averaged colour difference ΔE_{76} were evaluated for all twelve prints and four light exposure tests. The cumulative light exposure, which is the product of illuminance (lx) by duration (h), was applied to x-axis because light intensity of four light exposure testing is different to each other.

Examples of three types of prints are shown in Figure 4 (Sample A), Figure 5 (Sample E) and Figure 6 (Sample L).

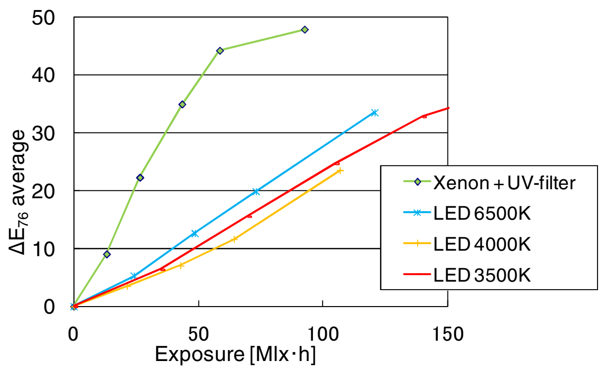

Figure 4. *Change in the averaged colour difference of Sample A*

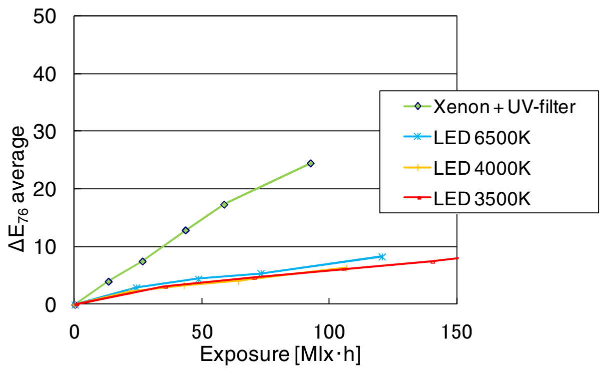

Figure 5. *Change in the averaged colour difference of Sample E*

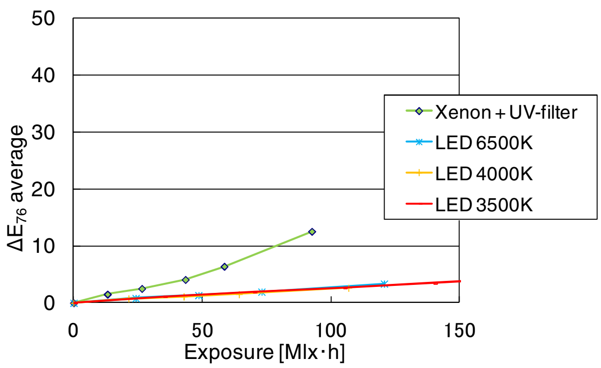

Figure 6. *Change in the averaged colour difference of Sample L*

Fading of print samples was observed under LED lighting for all of twelve (Sample "A" to "L") samples. But the extent of fading which is represented as the averaged colour difference ΔE_{76} was much smaller than xenon lighting. The difference among three types of colour temperature was not so large.

The averaged colour difference ΔE_{76} at the cumulative light exposure of 35Mlx·h is shown in Figure 7. Fading under three types of LED lighting was much smaller than xenon lighting for all twelve samples. It is concluded that these types of LED lighting are less aggressive than the xenon lighting with UV-filter, which simulates indirect daylight of typical home display. This might be because these types of LED lighting have less UV component as shown in Figure 2.

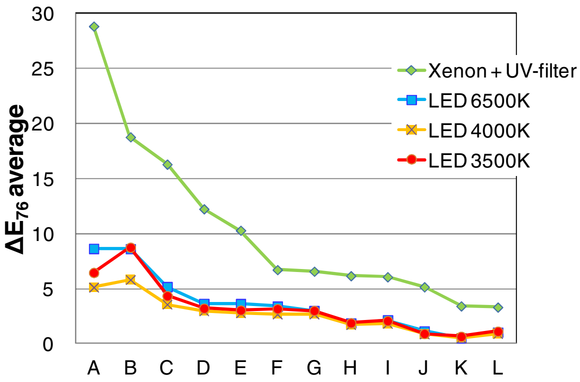

Figure 7. *Results of twelve prints at 35Mlx·h*

The fading order of twelve prints was compared between xenon testing and LED testing. The ΔE_{76} values of xenon testing at 35 Mlx·h and that of LED testing (LED 4000K) at 105 Mlx·h are plotted in Figure 8. Test results of xenon correlated well to those of LED and xenon lighting is about three times aggressive compared to LED lighting.

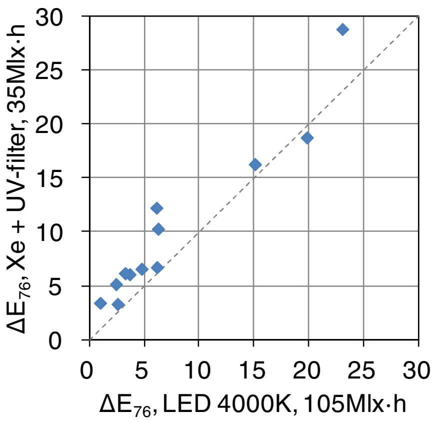

Figure 8. *Comparison of xenon testing and LED testing*

As an acceleration light exposure testing to evaluate or identify the potential of prints, LED lighting tests are so much time consuming. Xenon testing which is stipulated in ISO can be applied for this purpose because it takes less time and correlates well to LED testing as stated above.

Conclusion

Light stability tests under several types of white LED lighting with specific peak at 450nm, which is the most commonly used for indoor illumination, were performed.

(1) Fading under LED lighting is much smaller than xenon lighting with UV-filter which simulates indirect daylight of typical home display. It is assumed that photographic prints have three times longer lifetime in comparison with indoor indirect daylight.
(2) The difference in colour temperature of LED lamps has not much effect in fading behavior between 3500K and 6500K.
(3) Xenon testing is faster and correlates well to LED testing. It can be still appropriate to evaluate prints for overall light stability indoor.

References

[1] ISO 18937:2014, Imaging materials – Photographic reflection prints – Methods for measuring indoor light stability
[2] Y. Shibahara, E. Groen, N Uchino, Evaluation of the Image Permanence of Digital Colour Photographic Prints based on Colour Difference, Proceeding of NIP31, p 135-139 (2015).
[3] ISO 13655: Graphic technology – Spectral measurement and colorimetric computation for graphic arts image.
[4] ISO 11664-4: Colorimetry – Part 4: CIE 1976 L*a*b* Colour space.

Author Biography

Hiroshi Ishizuka obtained a master's degree in engineering from Tokyo Institute of Technology in 1989. He has worked on development of imaging and display materials in Fujifilm. His work is now focused on international standards for those materials. He is an expert of ISO/TC42 (photography) and IEC /TC110 (electronic display devices).

Evert Groen obtained a bachelor's degree in engineering in 1984 and joined Fujifilm in 1991. He had been involved in research and development of silver halide color photographic film and paper for more than a decade. He was manager of the technical market support and currently business development / key account manager. He is focused on International Standardization by participation as expert.

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Yoshi Shibahara obtained a master's degree in engineering from Japan's Kyoto University in 1978 and subsequently joined Fujifilm. Now, he is an advisory staff of the Fujifilm with the focus on International Standardization of digital printing and electronic displays. He also holds some important positions in the ISO and IEC, such as the Secretary of the IEC/TC 110 (electronic display devices), and the Convenor of ISO/TC 42/WG 3 (image measurement).

Shin Soejima obtained a master's degree from Science University of Tokyo in 1994 and started to work at Fujifilm. He had been involved in research and development of silver halide color photographic paper for a decade. And now, he is a general manager of international standards promotion office in IP headquarter division in Fujifilm.