Final Measurement and Verification Report for I&T Trial Project

Nanotechnology Optical Reflective Coating in Lighting Fixture in Office Areas

I&T Project No. : P-0034
I&T Wish No. : W-0134
I&T Solution No. : S-0074

E&M InnoPortal

EMSD

Copyright Notice And Disclaimer

Copyright Notice

Disclaimer

Table of Contents

Purpose of the Project and Target Deliverables

To promote the development of startups and the workplace comfort standard, Carbon Exchange was invited to conduct a trial project at the Vehicle Office of the Siu Ho Wan Government Maintenance Depot (SHWGMD). Their nano-optical reflector coating may improve performance in illuminance, which may also increase energy efficiency. They have installed lighting fixtures and conducted light quality survey in comparison with traditional lighting reflector.

Project Description

EMSD has commissioned Messrs. Carbon Exchange (Hong Kong) Ltd to carry out an I&T project utilizing the nanotechnology optical reflective coating in lighting fixture at the Vehicle Office of the Siu Ho Wan Government Maintenance Depot (SHWGMD) from 1 November 2018 to 13 March 2019.

After the measurement & verification exercise (M&V), it was verified that the use of nano-optical reflector (NOR) coated with nano-size pigment shall perform better than the traditional double parabolic aluminum reflector with more diffusion reflection and even light intensity, thereby enhancing the reflection efficiency. M&V results show that the average illuminance level and uniformity have been increased by more than 5% and 12% respectively after replacement with NORs. The NOR can improve performance in illuminance, thereby providing rooms for de-lamping opportunities on energy reduction.

Trial Site

The lighting fixtures are installed at the Vehicle Office of the Siu Ho Wan Government Maintenance Depot (SHWGMD).

Type of Equipment/ Installation/ Technology Adopted

Traditional double parabolic aluminum reflector is generally made by aluminum (mirror-like surface) which provides high specular reflection and low diffuse reflection, this feature causes uneven light intensity in different area and decrease in the efficiency of reflection.

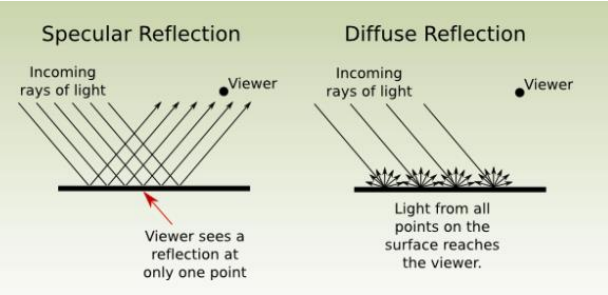

Figure 1. The difference of specular reflection and diffuse reflection.

The NOR on trial is coated by nano-oxide (nano-size pigment) to enhance the wide angle reflection, which provides a better performance of diffuse reflection attributed to strong diffraction of incident light, so as to achieve energy saving and improve the lighting quality such as uniformity and glare.

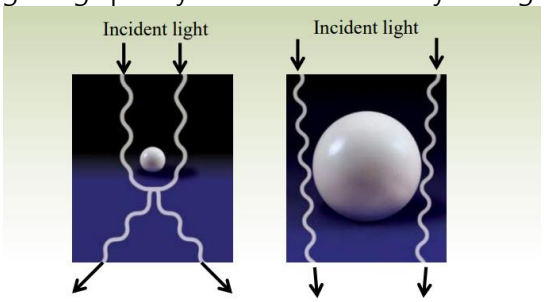

Figure 2. The diffraction of light around particles with different sizes.

In the environmental aspect, mirror-like metallic finish inside lighting reflector is either coated with electroplating or vacuum deposition. The former generates much toxic waste water with heavy metals that needs to be treated by expensive facilities before being discharged. The latter entails huge equipment cost and running cost. Comparatively, the nano-oxide coating costs less because it can be sprayed on or dip-coated at rather low temperature and atmospheric pressure without harming the environment.

Table 1. The Performance of Aluminum Reflector and NOR

	Aluminum reflector	NOR
Direct Reflectance	95%	95%
Diffuse Reflectance	50%	95%
Functional Life Time	>10 years	10 years

Trial Timeframe

The trial time is from 1 November 2018 to 13 March 2019.

Name and Background of I&T Solution Provider

Carbon Exchange (Hong Kong) Limited was established by team and alliance of local professional engineers, environmental research professional, energy management specialist in Hong Kong since 2010. They deliver consultancy services and environmental solutions for corporate clients by means of carbon and energy management approaches for satisfying clients' demands of energy cost savings, statutory compliance, CSR, in-house benchmarking, environmental performance evaluation and planning, etc. for projects at Hong Kong and overseas. Their products focus on energy management, lighting and Indoor Air Quality.

Details of Implemented Trials

I. Methodology and Applicable Standards

Lighting quality survey comparison

Eight (8) out of total twelve (12) numbers of existing lighting trays which were completed with double parabolic metallic-finished light reflectors, have been replaced by new lighting trays completed with LampMateTM Nano Optical Reflectors. Lighting quality surveys were conducted to identify the changes of lighting level and quality in the office before and after the lighting retrofit. Changes in power consumption of the concerned lighting installation is also recorded. Performance of lighting quality is further evaluated by the approach of "High Dynamic Range Photography Measurement".

Energy consumption measurement and lighting quality survey were conducted to identify the changes after the replacement. The lighting quality survey included illuminance level measurement at working level (i.e. 0.8m from the ground) and sitting eye level (i.e. 1.2m from the ground); and the high dynamic range photography measurement to identify the unified glare rating (UGR) against the SLL Code for Lighting (2012) from CIBSE.

II. Measurement and Verification Activity Details

Table 2. The Key Dates of Trial Project

Event	Date
Baseline Measurement	7 September 2018
Replacement of Reflectors	1 November 2018
1st Measurement	12 November 2018

2nd Measurement	13 March 2019

Summary Results and Analysis

I. Pre and Post-installation Comparison

With the aim to verify the improvement on energy efficiency and lighting quality of NOR over the traditional reflector (i.e. aluminum reflector), eight (8) out of twelve (12) numbers of existing 3x2feet 14W T5 florescent tube lighting trays with double parabolic metallic-finished light reflectors have been replaced by NORs at the reception office of SHWGMD (Figure 3).

Figure 3. The layout plan of lighting installations of reception office.

II. I.

Photo 1. The differences of NOR and traditional lighting trays.

II. Key Statistics/ Figures/ Infographics to Support the Results

Table 3. Improvement in Illuminance

	Average Illuminance (lux)		Percentage Change	
	Aluminum Reflector	NOR	Each Level	Weighted Average
Work-plant	371.8	433.4	+2.8%	-
Sitting Eye-level	548.7	564	+16.6%	
Average	460.25	498.7	-	+8.4%

Table 4. Improvement in Uniformity

	Uniformity		Percentage Change	
	Aluminum Reflector	NOR	Each Level	Weighted Average
Work-plant	0.68	0.82	+20.6%	-

Sitting Eye-level	0.62	0.71	+14.5%	
Average	0.65	0.765	-	+17.7%

Table 5. The Performance in UGR

	Aluminum Reflector		OR	
	UGR	Average lux	UGR	Average lux
Scenario 1: Three tubes per tray				
Direction A	20.94	371.8	19.96	433.4
Direction B	11.67		13.36	
Scenario 2: Two tubes per tray				
Direction A	17.65	266	18.27	315.5
Direction B	12		11.8	

Table 6. Saving in Energy Consumption

Type of Reflector	Lighting Type	Rated Power (W)	Ballast Power (W)	Total Power (W)	Quantity	Average Daily Operation Hour (hrs)	Estimated Daily Energy Consumption (kWh)
Aluminum	T5 tube	14	1.4	15.4	24	10	3.7
NOR					16	10	2.46
Estimated daily saving by removal of total 8 nos. of light tubes (kWh):							1.24
Percentage of estimated daily energy saving:							-33.5%

III. Analysis of M&V Results to Address the Target Deliverables

In order to verify the improvement on lighting quality, measurement on illuminance level, uniformity and UGR were conducted before and after replacement of NORs.

C.1 Illuminance level

For the illuminance level measurement, 8 measurement points were selected at working level (i.e. 0.8 meters above the ground), and 12 points were selected at sitting eye level (i.e. 1.2 meters above the ground). The distribution of the measurement points were shown in the Figure 4 and 5 below.

Figure 4. The measurement points at working level.

Figure 5. The measurement points at sitting eye level.

Regarding the measurement results, the average illuminance has been increased by 8.4% as detailed in the Table 3 below.

Table 3. Improvement in Illuminance

	Average Illuminance (lux)		Percentage Change	
	Aluminum Reflector	NOR	Each Level	Weighted Average
Work-plant	371.8	433.4	+2.8%	-
Sitting Eye-level	548.7	564	+16.6%	
Average	460.25	498.7	-	+8.4%

C.2 Uniformity

Based on the illuminance measurement result and the equation below, the changes in uniformity were also be calculated. There was increase of 17.7% in uniformity after using NORs as shown in Table 4.

$$\text{Uniformity} = \frac{\text{minimum illuminance amount the points}}{a\text{average illuminance amount the points}}$$

Table 4. Improvement in Uniformity

	Uniformity		Percentage Change	
	Aluminum Reflector	NOR	Each Level	Weighted Average
Work-plant	0.68	0.82	+20.6%	-
Sitting Eye-level	0.62	0.71	+14.5%	
Average	0.65	0.765	-	+17.7%

Referring to the Society of Light and Lighting (SLL) Code for Lighting (2012), the recommended minimum illuminance level and uniformity for office are 300 lux

and 0.6 respectively. In view of the above results, delamping one tube for each lighting tray was considered possible and the proceeded to reduce the energy consumption while maintaining the acceptable lighting quality.

The average working plane illuminance and uniformity were 315.5 lux and 0.78 respectively after delamping. The performance maintained up to the recommendations in the SLL Code for Lighting (2012).

C.3 Unified Glare Rating

Unified glare rating (UGR) which is expressing the discomfort glare caused by the lighting installation was further evaluated by the approach of "High Dynamic Range Photography Measurement". The UGR was measured in two viewing directions namely A and B as shown in the Figure 6 below.

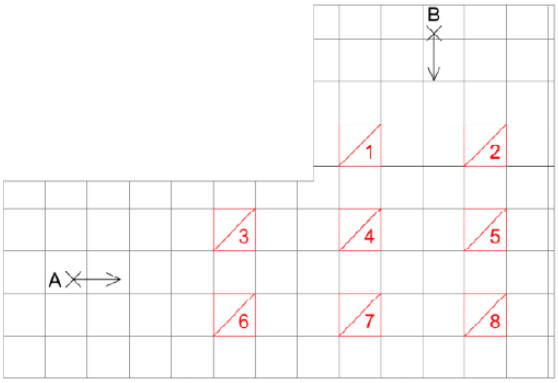

Figure 6. Measurement Direction under High Dynamic Range Photography Measurement.

In accordance with the SLL Code for Lighting (2012), the recommended UGR limit for office is 19. In other words, the lighting glare condition is acceptable if the UGR is equal or less than 19.

Table 5. The Performance in UGR

	Aluminum Reflector		NOR	
	UGR	Average lux	UGR	Average lux
Scenario 1: Three tubes per tray				
Direction A	20.94	371.8	19.96	433.4
Direction B	11.67		13.36	
Scenario 2: Two tubes per tray				
Direction A	17.65	266	18.27	315.5
Direction B	12		11.8	

The results as shown in Table. 5 that regardless of the use of aluminum reflector or NOR, the glare problem of the view from Direction A was always more serious than Direction B; and the UGR from Direction A exceeded the recommended limit under Scenario 1. In some cases, the UGR was increased after replacement

of NORs. This phenomenon was possibly due to the increase of illuminance level after using the high reflective NORs.

Taking all factors including illuminance, uniformity and UGR into consideration, the scenario of using NOR with two tubes per tray are the most cost-effective option to provide best lighting quality under the requirement of the SLL Code of Lighting (2012).

C.4 Energy Consumption

As one tube was removed from each lighting tray after using the NORs, such deduction of tubes have resulted in energy saving. The estimated and actual energy saving were presented as follows:

Table 6. Saving in Energy Consumption

Type of Reflector	Lighting Type	Rated Power (W)	Ballast Power (W)	Total Power (W)	Quantity	Average Daily Operation Hour (hrs)	Estimated Daily Energy Consumption (kWh)
Aluminum	T5 tube	14	1.4	15.4	24	10	3.7
NOR					16	10	2.46
Estimated daily saving by removal of total 8 nos. of light tubes (kWh):							1.24
Percentage of estimated daily energy saving:							-33.5%

An energy meter was permanently installed to measure the energy consumption of 8 sets of lighting trays under trial. The record showed that the average daily energy consumption after replacement of NOR and delamping has reduced by 1.63kWh (i.e. 37.5%) which alighted with the estimation of 1.24kWh.

Conclusion and Way Forward

In accordance with the aforesaid measurement results, the average illuminance level and uniformity have been increased by more than 5% and 12% respectively after replacement of NORs. Although, the UGR has been slightly increased which is possibly due to the increase of illuminance after using the NOR reflectors. It is believed that the UGR could be further improved by altering the lighting layout and luminaire design.

This I&T trial proved that the application of NOR reflectors is useful and economical to not only improves the lighting quality but also provides a room for de-lamping to reduce the energy consumption even keeping the luminaire unchanged.

For way forward, it is therefore recommended to adopt NOR in the future installations in government premises. We circulate the subject M&V report to ArchSD and internal strategic business units for reference to facilitate their upcoming plan on the alteration, addition and improvement project works of lighting systems either in new or existing venues.

- END OF REPORT –

Digitalisation and Technology Division

Electrical and Mechanical Services Department

29 April 2019