機電工程署
EMSD







LED 的一般照明用途
General Lighting Application

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1. Introduction

The purpose of this booklet is to provide general information on Light Emitting Diode (LED) lighting technology for general lighting purpose. Some examples of local applications of LED general lighting will also be included in this booklet.

2. What are LEDs?

Light Emitting Diodes (LEDs) are solid-state semiconductor devices that convert electrical energy into visible light. The semiconductor LED chip is supported by a reflector and encapsulated with an epoxy lens for controlling light distribution. When DC voltage is applied, the electrons flowing through the chip will cause emission of electromagnetic wave (light) at certain frequency (colour). Emitting monochromatic visible light of different colour is made possible by selecting different semiconductor materials.

LEDs were first deployed as indicator lights and digital display for electronic device such as calculators and watches many years ago. As the technology developed with improved power output and variety of colour, LEDs were used for signages, traffic lights and facade lighting applications. LEDs of traffic light emit light of an intended colour without using any colour filters as traditional lighting methods need. This is more energy efficient.

1. 引言

本小冊子旨在提供一些使用發光二極管（LED）照明技術作一般照明用途的資料，並介紹數個LED燈在本港作一般照明用途的應用實例。

2. 什麼是 LED?

發光二極管（LED）是固態的半導體器件，可把電能轉化為可見光線。LED是將一顆半導體晶片嵌裝在反射器上，再以樹脂密封，形成一片導引光線散發的鏡片。當接上直流電源，流經晶片的電流會使晶片產生某一頻率（或顏色）的電磁波（或光線），不同的半導體的物料，可令LED發出不同顏色的光線。

LED在多年前先應用於指示燈和在電子設備(例如計算器和手錶)上的數碼顯示。隨著技術發展與輸出功率的改進和顏色日趨多樣化，LED繼而應用於指示牌，交通燈和大廈外牆照明。有別於傳統照明方法，LED交通燈無須使用顏色過濾器便能發出所需的顏色，因此更具能源效益。

3. LED Lamps for General Lighting Purpose

3.1 Construction of LED Lamp

A LED lamp is made up of the following major components:

1. Light source : LEDs, in a package, or mounted on a circuit board ;
2. Optics : Phosphors in silicone gel, or, in a plastic lens, micro-structure lenses for beam pattern control and reflectors ;
3. Electrical / electronic components : circuit board ; AC or DC transformer; circuit driver; feedback loops and sensors; on / off / dimming control; and
4. Mechanical and thermal components : conductive adhesives and heat sink.

LED exit sign
LED出口指示牌

3. LED 燈作一般照明用途

3.1 LED燈的構造

LED燈的主要組件包括：

1. 光源：LED（封裝件或安裝在電路板上）
2. 光學儀器：混有磷的矽凝膠或塑料透鏡、控制光束模式的微結構透鏡片和反射器
3. 電氣／電子組件：電路板，AC或DC變壓器，電路驅動器；反饋迴路和感應器；開關或光暗調校器；以及
4. 機械和熱組件：導電黏合劑和散熱器

LED signage
LED指示牌

LEDs emit light in small band of wavelengths, producing coloured light. LEDs use following methods to create white light for general lighting purpose:

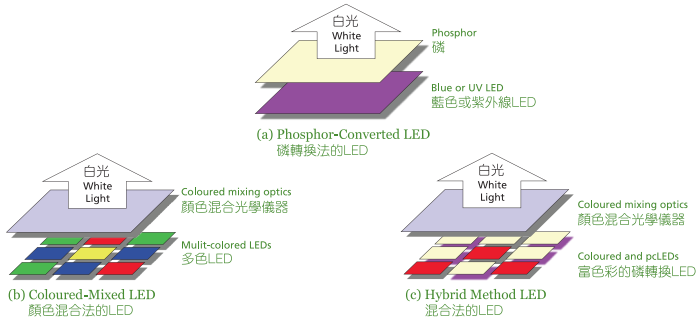
1. Colour mixing - Uses three individual LED chips (red, green and blue) each emitting a different wavelength in close proximity, to form the broad white light spectrum;
2. Phosphor conversion - Uses blue or ultra-violet LED to combine with phosphor;
3. Hybrid - combine phosphor conversion and colour mixing approach.

The colour mixing approach can achieve the highest efficacy white lights although the light is more sensitive to colour shift arising from temperature and aging. Whereas, the phosphor conversion approach will produce white light with good colour rendering index (CRI) and high efficacy. Currently, most LEDs adopt phosphor conversion approach to produce white light because of lower production cost and good CRI for general lighting purpose.

LED在小段波長範圍內發出光線，產生彩光。LED透過以下方法產生白光作一般照明用途：

1. 顏色混合法 – 使用三顆獨立的LED晶片（紅色、綠色和藍色），每顆晶片在近距離發出不同波長的光線，組成寬的白色光譜；
2. 磷轉換法 – 使用藍色或紫外線LED與磷結合；
3. 混合法 – 結合磷轉換法與顏色混合法。

顏色混合法可以產生光效最高的白光，但光線較易因溫度和老化而出現色偏。磷轉換法產生的白光在顯色指數和光效方面都表現良好。由於磷轉換法成本較低和顯色指數高，現時大部分LED都是以這種方法產生白光作一般照明用途。



Methods of generating LED white light for general lighting
產生LED白光作一般照明的方法

LED performance largely depends on the ambient temperature of the operating environment. Hence, quality LED luminaires require precise design of several components including LED arrays, electronic drivers, heat dissipation, luminaires casing and optics in order to provide good thermal management for efficient, long service life and reliable operation of LED luminaries. Over-driving an LED in high ambient temperatures may result in overheating the LED package, eventually leading to device failure. Inappropriate drivers may also limit the lifetime of an LED package, hastening lumen depreciation, by overstressing the LED.

LED general lighting products can be broadly classified into two categories, namely the LED lamps and the LED luminaires.

3.2 LED Lamps

LED lamps are those that can fit into the existing lamp caps. They can directly replace ordinary incandescent lamps, reflector / PAR lamps and compact fluorescent lamps. These include:

- Self-ballasted LED general service lamps with E27 or E14 caps;
- Self-ballasted LED candle lamps with E14 or B22 or E12 caps;
- Non-self-ballasted LED MR16 lamps with GU5.3 or GU10 caps;
- Self-ballasted LED reflector / PAR lamps;

LED的性能在很大程度上取決於操作環境的溫度。因此，優質LED燈具的多個組件（包括LED陣列、電子驅動器、散熱、燈具外殼和光學儀器）都必須設計精確，以提供良好的散熱管理，令LED燈具發揮高效、使用壽命長及運作可靠的優點。在高環境溫度下過度驅動LED，可能會令LED封裝件過熱，最終導致裝置故障。不適當的驅動程序也會令LED過勞，縮短LED封裝件的使用壽命，加速光衰。

LED一般照明產品大致可分為兩類，即LED燈泡與LED燈具。

3.2 LED燈泡

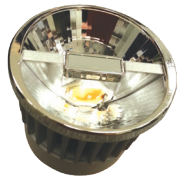
LED燈泡是那些能與現有燈頭配合使用的燈泡，可直接替代普通的鎢絲燈泡、反射／PAR燈泡和慳電膽。這類LED燈泡包括：

- 配備鎮流器的LED普通照明燈連E27或E14燈頭；
- 配備鎮流器的LED蠟燭燈連E14或B22或E12燈頭；
- 無配備鎮流器的LED MR 16燈GU5.3或 GU10燈頭；
- 配備鎮流器的LED反射／PAR燈；

LED lamp
LED燈泡

LED MR16 lamp
LED MR16 燈

LED candle lamp
LED 蠟燭燈



LED PAR reflector lamp
LED 反射燈

LED lamps offer viable alternative for direct replacement of incandescent lamps and halogen lamps because of their higher efficacy, longer service life and high colour rendering index (CRI). The following table compares the properties of majority products of LED lamps, halogen lamps and incandescent lamps in the market:

由於LED燈光效較高、壽命較長和顯色指數高，因此是直接替代鎢絲燈和石英燈泡(或稱鹵素燈泡)的一個可行選擇。下表比較市場上大多數的LED燈泡、石英燈泡和鎢絲燈泡產品的屬性：

Types of lamps 種類	Luminous Efficacy (lumens/Watt) 發光效率（流明／瓦）	Life Expectancy (hours) 壽命(小時)	Colour Rendering Index (CRI) 顯色指數(CRI)
LED lamps LED燈泡	60 - 130	15 000 - 30 000	70 - 95
Tubular fluorescent tubes 光管 (T5/T8)	80 - 110	15 000 - 30 000	60 - 95
Compact fluorescent lamps (CFL) 慳電膽	50 - 70	6 000 - 15 000	70 – 85
Tungsten halogen lamps 石英燈泡	11 - 21	2 000 - 3 000	98 - 100
Incandescent lamps 鎢絲燈	8 - 17	1 000 - 1 500	98 - 100

Remarks: The figures are made reference to "Accelerating the Global Adoption of Energy Efficient Lighting" published by UN Environment in 2017

備註：以上數據是參考聯合國環境署於2017年出版的 "Accelerating the Global Adoption of Energy Efficient Lighting"

For wall wash application, LED MR16 lamps are good replacement for low voltage (LV) halogen MR16 lamps as they can be directly fitted into the lamp fittings. A 6W LED MR16 lamp uses about 80% less energy than a traditional 50W tungsten halogen lamp and lasts at least 10 times longer. LED lamp produces much less heat, so it is safer to operate and can cut energy costs associated with space air conditioning. LED MR16 lamps are now dimmable, come in a range of different colour temperature. As LED lamps do not emit infrared or ultraviolet rays, they are particularly suitable for illuminating heat-sensitive objects such as pictures and paintings etc. The infrared rays from halogen lighting will raise room temperatures, thus increasing the air conditioning load.

在牆掛式照明方面，由於LED MR16燈可以直接裝進石英燈泡的燈座，因此適合用作替代低壓MR16石英燈泡。一個6瓦的LED MR16燈泡耗電量較傳統的50瓦石英燈泡耗電量少約80%，而使用壽命至少長10倍。LED燈亮時只產生極少熱量，故此在運作上更為安全，也能減低空調的電費。LED MR16燈泡現可調校光暗，有一系列不同的色溫。由於LED燈泡不會放射紅外線或紫外線，特別適合為易受熱力影響的物件，例如照片和畫作等提供照明。石英燈泡發出的紅外線會令室溫上升，因而增加空調負荷。

3.3 LED Luminaires

LED luminaires can be grouped into two types of applications, including interior lighting and exterior lighting applications.

For interior application, LED luminaires include LED downlights, LED spotlights, LED lighting panels and portable task lights.

LED downlights are available widely in a range of sizes, recessed type and service mounted. Different lumen packages are also available, offering viable solution for conventional light fitting replacement.

3.3 LED燈具

LED燈具的應用可分為兩種，即室內照明和戶外照明。

在室內照明方面，LED燈具包括LED筒燈、LED射燈、LED燈盤和便攜式工作燈。

LED筒燈分為嵌入式和表面裝置式，備有多種尺碼可供選擇，並有不同光度組合，為更換傳統燈具提供可行的解決方案。

LED desk lamps penetrate fast into the portable desk lighting market. Most LED desk lamps can continuously dimmable, have longer service life and more energy efficient over their incandescent and compact fluorescent lamp (CFL) counterparts.

LED枱燈在便攜式枱燈市場迅速崛起。大部分LED枱燈均可連續調校光暗度，較鎢絲燈和慳電膽枱燈更耐用，能效更高。

Recessed type LED lighting panel
嵌入式LED燈盤

LED desk light
LED枱燈

LED spot light
LED射燈

Recessed LED downlight
嵌入式LED筒燈

For exterior applications, LED luminaires include floodlights and street lights. Compared with conventional outdoor lights such as metal halide and high pressure sodium light sources, well-designed LED outdoor luminaires can provide required surface illuminance using less energy and with improved uniformity. LED outdoor luminaires may also have significantly longer service life with better lumen maintenance. However, moisture incursion can be an important determinant of service life of LED luminaires.

在戶外照明方面，LED燈具包括泛光燈和路燈。與傳統的戶外燈如金屬鹵化素燈和高壓鈉燈的光源相比，設計精良的LED戶外燈具能以較少能源來提供所需的表面照明度，而均勻性亦更高。LED戶外燈具的使用壽命顯著較長，其光通維持率亦較佳。然而，濕氣入侵可能會嚴重影響到LED燈具的使用壽命。

LED floodlight
LED泛光燈

LED street light
LED路燈

Unlike other traditional light sources, LED lights emit light directionally to where it is needed. This reduces wasted light and avoids overspill of light to outside the area being lit up. However, the external lighting design shall avoid the possibility of shining outside the area it intends to light up, affecting neighbourhood or the sky. If so, refine the lighting design, consider re-positioning the lightings and adjusting the aiming angles, and choose luminaires with suitable light distribution characteristics (e.g. light pattern, beam spread, cut-off angle) or light control devices (e.g. shields and baffles) as appropriate. Whenever there is residence nearby, use lighting with appropriate shields, baffles, louvers and cut-off features to prevent light overspill, and glare from the light source.

與其他傳統光源不同，LED燈的光源會定向照射到需要照明的地方。這減少光源的浪費，也避免光源流溢到照射範圍以外的地方。但是，戶外燈具在照明設計上應盡量避免照射到所需照射範圍以外的地方，以免影響鄰舍或天空。如出現上述情況，應改善照明設計，考慮更改燈具的位置，調整瞄準角度，並選擇具合適光分布特徵（例如光圖案，光束擴展，截光角）、或配備適用燈光控制裝置（如護罩和擋板）的燈具。若附近有住宅，應使用適當的護罩、擋板、遮光板和截光功能，以防止光線流溢和光源產生眩光。

4. Advantages of Using LED

For general lighting purpose, LED lighting have the following superior features over conventional lighting technologies.

4.1 Robust and Reliable

LEDs are inherently rugged and have no filament to break. They are difficult to damage with external shock, unlike fluorescent and incandescent bulbs, which are fragile.

4.2 Long Service Life

The service life of LED is mainly determined by the depreciation of light output. A LED is generally considered reaching its end of life when its light drops by more than 30%, i.e., 70% lumen maintenance. Some high quality LED luminaires that work properly within its temperature limit will last about 25,000 to 50,000 hours, which is about 3 to 6 times as long as compact fluorescent lamps, and far longer than typical incandescent lamp with service life of about 1,000 hours. Long service life makes LED particularly suitable for use in areas with harsh maintenance constraints.

4. 使用LED的優點

就一般照明而言，LED照明較傳統照明技術優勝的地方為：

4.1 堅固可靠

LED本身堅固耐用，由於沒有燈絲，所以不會有燈絲折斷的問題。LED燈泡不易因外部衝擊而損壞，不像熒光燈和鎢絲燈燈泡般易碎。

4.2 耐用

LED極耐用，其使用壽命主要取決於其光通量的衰減程度。一般情況是，當LED的光通量下降逾30%（即70%光通維持率）時，便可視作使用期滿。如在不超溫的情況下正常運作，高質素LED的壽命可達25,000至50,000小時，比慳電膽長約3倍至6倍，比一般鎢絲燈約1,000小時的壽命長更多。由於使用壽命長，在一些維修限制嚴苛的場地，LED便能大派用場。

4.3 Versatile Colour Changes

LED can be switched on and off instantly. It is also suitable for uses subject to frequent on-off cycling, unlike fluorescent lamps that fail faster when cycled often, or high intensity discharge lamps that require a long re-strike time. Since LED responds quickly to both switching and dimming, it is very suitable for dynamic lighting effect. This can easily be done with digital controller and computer programme.

4.4 Environmental Friendly

LED is comparatively more environmentally friendly than conventional lamps. It emits more light per watt than incandescent light bulbs. It will not produce ultraviolet (UV) or infrared (IR) radiation. No mercury

4.3 色彩變化多

LED可以即時啟動和關上，不像熒光燈般會因頻密開關而加速失效，或像高強度氣體放電燈般需要很長的重燃時間，因此適用於頻密開關。由於LED對開關和調控訊號反應迅速，因此非常適用於營造閃動及變幻的照明效果，只要配備數碼控制器和電腦控制程式，即可輕易取得上述效果。

4.4 保護環境

LED燈比傳統燈泡環保。相比鎢絲燈，LED燈每瓦可發出更多的光。LED不會產生紫外線（UV）或紅外線（IR）。製造LED燈時也無需使用水銀。由於

LED indicator
LED指示燈

LED facade lighting
使用LED作大廈外牆照明

is used in the manufacturing of LEDs. LED has a much longer service life and hence helps waste reduction. However, LED drivers are electronic devices and their disposal may still be a concern.

LED燈更耐用，因此有助減少廢物產生。然而，LED驅動器是電子設備，如何處置也是需要關注的問題。

5. Challenges of LED Products

5. LED產品的挑戰

As LED technology is still under development, the quality of LED products in the market varies widely. Individual manufacturers adopt their own testing methodologies and there may be wide disparities between actual and claim performance. Major quality concerns on LED lamp and luminaires are life expectancy, colour shifts, optics degradation and even catastrophic failure etc.

由於LED技術仍在發展中，市場上的LED產品質量參差。個別廠家各有自己的測試方法，實際和聲稱的性能因此可能差別甚大。對LED燈泡及燈具的質量關注，主要是壽命、色彩偏移、光學退化和嚴重故障等。

The LED lighting and its control gear such as lamp driver shall comply with relevant electromagnetic compatibility standards. LED modules and luminaire shall comply with relevant environmental and safety standards, such as photo-biological safety. For general reference, guidelines for specifying and procuring LED lighting products for lighting projects are available at EMSD website (www.emsd.gov.hk).

LED照明及其控制設備(如驅動器)必須符合相關的電磁兼容標準。LED模組和燈具也須符合相關的環保和安全標準，例如光生物安全。有關資料，可參考機電工程署網頁(www.emsd.gov.hk)內的規範及採購照明項目LED照明產品的指引。

Electrical and Mechanical Services Department (EMSD) has extended the scope of the Voluntary Energy Efficiency Labelling Scheme to cover most of the LED lamps. Details can be found at EMSD website. The Scheme aims to help consumers select more energy-efficient products, to achieve greater public awareness of energy conservation and environmental improvement needs.

機電工程署已把自願性能源效益標籤計劃的範圍擴大至涵蓋大部分LED燈泡。詳情可參考機電工程署網頁。這項計劃旨在幫助消費者選擇更節能的產品，以及提高公眾對節能和改善環境的意識。

6. LED Lighting Applications in Hong Kong

6. 本港的LED照明應用實例

6.1 Hong Kong International Airport

6.1 香港國際機場

As part of the airport's environmental programme, Airport Authority Hong Kong (AA) has committed to replace existing lighting with 100,000 LED lights in passenger terminals by the end of 2014.

作為機場環保計劃的一部分，香港機場管理局承諾於2014年年底前，以10萬枚LED燈取代客運大樓現有的照明裝置。

Replacement of metal halide floodlights with LED luminaries at Terminal 2
將二號客運大樓內的金屬鹵化素泛光燈更換為LED燈

Replacement of SON lamps with LED luminaries at Staff Carpark
將員工停車場內的SON燈更換為LED燈

This environmental programme will save approximately 15 million kWh of electricity and reduce nearly 9,000 tonnes of carbon emissions per year.

透過這項環保計劃，估計每年可節省約1,500萬度電及減少近9,000公噸碳排放量。

Replacement of fluorescent luminaries and metal halide with LED luminaries at Automated People Mover Platform
將無人駕駛列車月台的熒光燈及金屬鹵化素燈更換為LED燈

Replacement of fluorescent luminaries with LED luminaries at Baggage Reclaim Hall
將行李認領大堂內的熒光燈更換為LED燈

6.2 MTR Stations and Trains

The MTR (Mass Transit Railway) Corporation of Hong Kong has carried out installations of LED lights on board trains and in stations. The programme involves replacement of fluorescent tubes with 35,000 LED lamps in 136 trains and 250 LED lamps in Choi Hung Station. It is estimated that the upgrading can cut down 55% and 25% of electricity consumption on lighting for trains and station respectively.

6.2 港鐵車站和列車

香港鐵路有限公司已在列車上和車站進行LED燈安裝計劃。該計劃已為136架列車安裝35,000枚LED燈及在彩虹站安裝250枚LED燈以取代熒光燈。估計這項改善計劃可為列車及車站分別減少55%及25%的照明耗電量。

LED lighting in MTR trains
港鐵列車上的LED照明設施

LED lighting in MTR Station
港鐵車站內的LED照明設施

LED lighting in Airport Express Line trains
港鐵機場快線列車上LED的照明設施

6.3 Public Housing in Hong Kong

LED lighting has also been used in some public rental housing estates of the Hong Kong Housing Authority such as LED for street lighting, landscape lighting, internal corridor lighting etc.

6.3 本港的公共房屋

香港房屋委員會的部分公共租住屋邨也有使用LED照明，例如把LED應用於街道照明、景觀照明、室內走廊照明等。

LED solar lamp in Public Housing Project
公共房屋項目的太陽能LED燈

LED panels in Public Housing Project
公共房屋項目的LED燈盤

LED floodlight in Public Housing Project
公共房屋項目的LED泛光燈

LED spot lamp in Public Housing Project
公共房屋項目的LED射燈

6.4 Government Buildings

Architectural Services Department has installed LED lighting in some government buildings such as general lighting at corridors, canteens, conference rooms, classrooms, assembly halls, parks, swimming pools, fountains, etc.

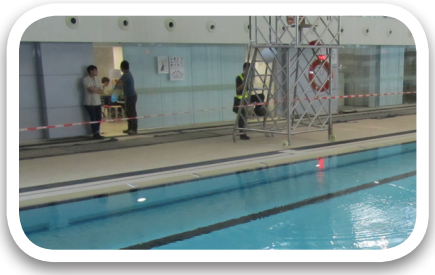
6.4 政府建築物

建築署已在部份政府建築物安裝LED照明設施，包括走廊、員工餐廳、會議室、課室、禮堂、公園、游泳池、水池等。

LED tubes for green board lighting at classroom
課室內用作綠板照明的LED光管

LED panel lighting at classroom
課室內的LED燈盤照明

LED down lights in the school hall
學校禮堂內的LED筒燈



LED underwater lighting at swimming pool
游泳池內的LED水底照明

LED down lights at conference room
會議室內的LED筒燈

LED down lights at corridor
走廊的LED筒燈

Dimmable LED down lights for house lighting
用作場館照明的可調光暗的LED筒燈

LED down lights at canteen
食堂內的LED筒燈

LED strip for step lighting
LED燈帶作梯級照明

LED bollard light at planter
花槽內的LED圓柱照燈

LED street lights at car park
停車場的LED路燈

Integration of LED lighting onto the handrail
融合於扶手攔杆的LED照明

LED strip lighting at the base of planters
花槽底的LED燈帶