IEC 60747-5-8

Edition 1.0 2019-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Semiconductor devices –
Part 5-8: Optoelectronic devices – Light emitting diodes – Test method of optoelectronic efficiencies of light emitting diodes

Dispositifs à semiconducteurs –
Partie 5-8: Dispositifs optoélectroniques – Diodes électroluminescentes – Méthode d'essai des efficacités optoélectroniques des diodes électroluminescentes

IEC 60747-5-8:2019-11(en-fr)

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 5-8: Optoelectronic devices – Light emitting diodes – Test method of optoelectronic efficiencies of light emitting diodes

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The text of this International Standard is based on the following documents:

CDV	Report on voting
47E/637/CDV	47E/658/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60747 series, published under the general title *Semiconductor devices*, can be found on the IEC website.

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SEMICONDUCTOR DEVICES –

Part 5-8: Optoelectronic devices – Light emitting diodes – Test method of optoelectronic efficiencies of light emitting diodes

1 Scope

This part of IEC 60747 specifies the terminology and the measuring methods of various efficiencies of single light emitting diode (LED) chips or packages without phosphor. White LEDs for lighting applications are out of the scope of this part of IEC 60747. The efficiencies whose measuring methods are defined in this part are the power efficiency (PE), the external quantum efficiency (EQE), the voltage efficiency (VE), and the light extraction efficiency (LEE). To measure the LEE, the measurement data of the internal quantum efficiency (IQE) is used, whose measuring method is discussed in IEC 60747-5-9[1] and IEC 60747-5-10[2]. The injection efficiency (IE) and the radiative efficiency (RE) are given definitions only.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content shall constitute requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60747-5-6:2016, *Semiconductor devices – Part 5-6: Optoelectronic devices – Light emitting diodes*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General terms and definitions

3.1.1
radiant power
Φ_e
power emitted, transmitted or received in the form of radiation

Note 1 to entry: The unit used is: W. Radiant power is also known as the “radiant flux”.

[SOURCE: IEC 60050-845:1987, 845-01-24, modified – The symbol has been added to the term and Note 1 has been expanded.]

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[1] Under preparation. Stage at the time of publication IEC RPUB 60747-5-9:2019.

[2] Under preparation. Stage at the time of publication IEC RPUB 60747-5-10:2019.

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3.1.2
spectral distribution

quotient of the radiant power $d\Phi_e$ contained in an elementary range $d\lambda$ of wavelength at the wavelength λ, by that range

$$\Phi_{e,\lambda} = \frac{d\Phi_e(\lambda)}{d\lambda}$$

Note 1 to entry: Spectral distribution is also known as “spectrum distribution”.

[SOURCE: IEC 60050-845:1987, 845-01-17, modified – In the definition, "or luminous or photon quantity $dX(\lambda)$" has been replaced by "power $d\Phi_e$", in the formula, X has been replaced by Φ_e; Note 1 has been updated and Note 2 deleted.]

3.1.3
mean photon energy
$h\bar{\nu}$
mean energy that each photon carries

$$h\bar{\nu} = \frac{\Phi_e}{\int \frac{\lambda}{hc} \Phi_{e,\lambda} d\lambda}$$

where

h is the Planck constant;

c is the speed of light in vacuum

3.2 Terms and definitions relating to the measurement of the efficiency

3.2.1
power efficiency
η_{PE}
ratio of the radiant power (coupled to free space), Φ_e, to the electrical power consumed by the LED, $V_F I_F$, where V_F is the forward voltage and I_F is the forward current of the LED

$$\eta_{PE} = \frac{\Phi_e}{V_F I_F}$$

Note 1 to entry Power efficiency is also known as “wall-plug efficiency”. Power efficiency is identical to the “radiant efficiency” when the power dissipated by any auxiliary equipment is excluded from the electrical power.

3.2.2
voltage efficiency
η_{VE}
ratio of the mean photon energy emitted from the LED to the electron energy given by the forward voltage of the LED, V_F

$$\eta_{VE} = \frac{h\bar{\nu}}{qV_F}$$

where

q is the elementary charge

Note 1 to entry: Voltage efficiency can be greater than 1 at very low forward currents.

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3.2.3
external quantum efficiency

η_{EQE}

ratio of the number of photons emitted into the free space per unit time to the number of electrons injected into the LED per unit time

$$\eta_{\mathrm{EQE}} = \frac{\Phi_{\mathrm{e}} / h\bar{\nu}}{I_{\mathrm{F}} / q}$$

3.2.4
internal quantum efficiency

η_{IQE}

ratio of the number of photons emitted from the active region per unit time to the number of electrons injected into the LED per unit time

$$\eta_{\mathrm{IQE}} = \frac{\Phi_{\mathrm{e,active}} / h\bar{\nu}}{I_{\mathrm{F}} / q}$$

where

$\Phi_{\mathrm{e,active}}$ is the radiant power emitted from the active region

3.2.5
light extraction efficiency

η_{LEE}

ratio of the number of photons emitted into the free space to the number of photons emitted from the active region

$$\eta_{\mathrm{LEE}} = \frac{\Phi_{\mathrm{e}}}{\Phi_{\mathrm{e,active}}}$$

3.2.6
injection efficiency

η_{IE}

ratio of the number of electrons injected into the active region per unit time to the number of electrons injected into the LED per unit time

$$\eta_{\mathrm{IE}} = \frac{I_{\mathrm{F,active}}}{I_{\mathrm{F}}}$$

where

$I_{\mathrm{F,active}}$ is the portion of the forward current injected into the active region

3.2.7
radiative efficiency

η_{RE}

<of the LED active region> ratio of the number of photons emitted from the active region per unit time to the number of electrons injected into the active region per unit time

$$\eta_{\mathrm{RE}} = \frac{\Phi_{\mathrm{e,active}} / h\bar{\nu}}{I_{\mathrm{F,active}} / q}$$

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Note 1 to entry The power efficiency can be decomposed into various constituent efficiencies as follows:

$$\begin{aligned}\eta_{\mathrm{PE}} &= \eta_{\mathrm{VE}} \cdot \eta_{\mathrm{EQE}} \\ &= \eta_{\mathrm{VE}} \cdot \eta_{\mathrm{LEE}} \cdot \eta_{\mathrm{IQE}} \\ &= \eta_{\mathrm{VE}} \cdot \eta_{\mathrm{LEE}} \cdot \eta_{\mathrm{IE}} \cdot \eta_{\mathrm{RE}}\end{aligned}$$

$$\eta_{\mathrm{EQE}} = \eta_{\mathrm{LEE}} \cdot \eta_{\mathrm{IQE}}$$

$$\eta_{\mathrm{IQE}} = \eta_{\mathrm{IE}} \cdot \eta_{\mathrm{RE}}$$

Using the efficiency definitions, the above can rewritten as:

$$\begin{aligned}\eta_{\mathrm{PE}} &= \frac{\Phi_{\mathrm{e}}}{V_{\mathrm{F}} I_{\mathrm{F}}} \\ &= \frac{h\bar{\nu}}{qV_{\mathrm{F}}} \cdot \frac{\Phi_{\mathrm{e}}}{\Phi_{\mathrm{e,active}}} \cdot \frac{I_{\mathrm{F,active}}}{I_{\mathrm{F}}} \cdot \frac{\Phi_{\mathrm{e,active}} / h\bar{\nu}}{I_{\mathrm{F,active}} / q}\end{aligned}$$

4 Measuring methods

4.1 Basic requirements

4.1.1 Measuring conditions

a) Temperature

If not specified, measurements shall be made at an ambient temperature (T_{a}) of (25 ± 3) °C in conditions of free air.

b) Humidity

When humidity conditions are not specified, relative humidity shall be between 45 % RH and 85 % RH.

c) Other conditions

In some cases, measurements change because of heat generation in the test LED over time. In that case, it is necessary to decide on the measurement time, otherwise the measurement shall be performed after reaching thermal equilibrium. Thermal equilibrium may be considered to have been achieved if doubling the time between the application of power and the measurement causes no change in the indicated result within the precision of the measurement instruments.

4.1.2 Measuring instruments and equipment

Measuring instruments and equipment shall be the same as given in 6.1.2 of IEC 60747-5-6:2016.

4.2 Power efficiency (η_{PE}) measurement

4.2.1 Purpose

To measure the power efficiency of the LED when a specified forward current is applied.

4.2.2 Measurement procedure

The measurement procedure is as follows:

a) Measure the radiant power (Φ_{e}) and the forward voltage (V_{F}) at a specified forward current (I_{F}).

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b) Calculate the power efficiency by taking the ratio of the radiant power (coupled to the free space), Φ_e, to the input electrical power $V_F I_F$, i.e.:

$$\eta_{PE} = \frac{\Phi_e}{V_F I_F}$$

NOTE 1 The measurement of the forward voltage at a specified forward current is given in 6.2 of IEC 60747-5-6:2016.

NOTE 2 The measurement of the radiant power at a specified current is given in 6.11 of IEC 60747-5-6:2016.

4.3 External quantum efficiency (η_{EQE}) measurement

4.3.1 Purpose

To measure the external quantum efficiency of the LED when a specified forward current is applied.

4.3.2 Measurement procedure

The measurement procedure is as follows.

a) Measure the radiant power (Φ_e) at a specified forward current (I_F).

b) Measure the emission spectrum distribution ($\Phi_{e,\lambda}$).

c) Calculate the mean photon energy ($h\bar{\nu}$) by using the following formula:

$$h\bar{\nu} = \frac{\Phi_e}{\int \frac{\lambda}{hc} \Phi_{e,\lambda} d\lambda}$$

d) Calculate the external quantum efficiency by taking the ratio of the number of photons emitted into free space per unit time to the number of electrons injected into the LED per unit time, i.e.:

$$\eta_{EQE} = \frac{\Phi_e / h\bar{\nu}}{I_F / q}$$

NOTE 1 The measurement of the radiant power at a specified current is listed in 6.11 of IEC 60747-5-6:2016.

NOTE 2 The measurement method of the emission spectrum distribution is listed in 6.15 of IEC 60747-5-6:2016.

4.4 Voltage efficiency (η_{VE}) measurement

4.4.1 Purpose

To measure the voltage efficiency of the LED when a specified forward current is applied.

4.4.2 Measurement procedure

The measurement procedure is as follows.

Calculate the voltage efficiency by taking the ratio of the power efficiency to the external quantum efficiency, i.e.:

$$\eta_{VE} = \frac{\eta_{PE}}{\eta_{EQE}}$$

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NOTE 1 For the measurement of the power efficiency, see 4.2.

NOTE 2 For the measurement of the external quantum efficiency, see 4.3.

4.5 Internal quantum efficiency (η_{IQE}) measurement

The measurement methods of the internal quantum efficiency are defined in other documents currently being developed.

4.6 Light extraction efficiency (η_{LEE}) measurement

4.6.1 Purpose

To measure the light extraction efficiency of the LED when a specified forward current is applied.

4.6.2 Measurement procedure

The measurement procedure is as follows.

Calculate the light extraction efficiency by taking the ratio of the external quantum efficiency to the internal quantum efficiency, i.e.:

$$\eta_{LEE} = \frac{\eta_{EQE}}{\eta_{IQE}}$$

NOTE 1 For the measurement of the external quantum efficiency, see 4.3.

NOTE 2 For the measurement of the internal quantum efficiency, see 4.5.

4.7 Measurement sequences

Figure 1 summarizes the measurement sequences of each efficiency of the LED when a specified forward current is applied. A test example is given in Annex A.

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