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colour inside

Semiconductor devices – Part 5-11: Optoelectronic devices – Light emitting diodes – Test method of radiative and nonradiative currents of light emitting diodes

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FOREWORD

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International Standard IEC 60747-5-11 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

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

CDV	Report on voting
47E/653/CDV	47E/678/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.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
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SEMICONDUCTOR DEVICES –

Part 5-11: Optoelectronic devices – Light emitting diodes – Test method of radiative and nonradiative currents of light emitting diodes

1 Scope

This part of IEC 60747 specifies the measuring methods of radiative and nonradiative currents of single light emitting diode (LED) chips or packages without phosphor. White LEDs for lighting applications are out of the scope of this document. This document utilizes the internal quantum efficiency (IQE) as a function of current, whose measurement methods are discussed in other documents.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes 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, definitions and abbreviated terms

3.1 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

3.1.1
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

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

where

$\Phi_{e,active}$ is the radiant power emitted from the active region
$h\bar{\nu}$ is the mean photon energy
I_F is the forward current
q is the elementary charge

[SOURCE: IEC 60747-5-8:2019, 3.2.4]

3.1.2
radiative current
I_{rad}
current that is consumed by the radiative recombination process in the LED

3.1.3
nonradiative current
I_{nonrad}
current that is consumed by the nonradiative processes in the LED

Note 1 to entry: The nonradiative processes in the LED include the nonradiative recombination in the active region and the carrier leakage outside the active region.

Note 2 to entry: The total forward current I_F supplied to the LED can be decomposed into radiative and nonradiative currents:

$$I_F = I_{rad} + I_{nonrad}.$$

Using the radiative and nonradiative currents, the IQE can be re-expressed as follows:

$$\eta_{IQE} = \frac{I_{rad}}{I_F} = \frac{I_{rad}}{I_{rad} + I_{nonrad}}.$$

Using the above relations, the radiative and nonradiative currents can be expressed as follows:

$$I_{rad} = \eta_{IQE} I_F;$$

$$I_{nonrad} = I_F - I_{rad} = (1 - \eta_{IQE}) I_F.$$

Electrical power consumed by the radiative process (P_{rad}) in the LED can be expressed as follows:

$$P_{rad} = I_{rad} V_F = \eta_{IQE} I_F V_F = \eta_{IQE} P$$

where P is the total electrical power dissipated by the LED: $P = I_F V_F$.

Electrical power consumed by the nonradiative processes ($P_{non\text{-}rad}$) in the LED can be expressed as follows:

$$P_{nonrad} = I_{nonrad} V_F = (1 - \eta_{IQE}) I_F V_F = (1 - \eta_{IQE}) P.$$

The power efficiency (η_{PE}) represents how much electrical power dissipated by the LED is converted to the radiant power (Φ_e):

$$\Phi_e = \eta_{PE} P.$$

Since $P = P_{rad} / \eta_{IQE}$ and $\eta_{PE} = \eta_{VE} \cdot \eta_{LEE} \cdot \eta_{IQE}$,

$$\Phi_e = \frac{\eta_{PE}}{\eta_{IQE}} P_{rad} = \frac{\eta_{VE} \cdot \eta_{LEE} \cdot \eta_{IQE}}{\eta_{IQE}} P_{rad} = \eta_{VE} \cdot \eta_{LEE} \cdot P_{rad}$$

or

$$\frac{\Phi_e}{P_{rad}} = \eta_{VE} \cdot \eta_{LEE}.$$

3.2 Abbreviated terms

LED light emitting diode

IQE internal quantum efficiency

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 a condition of free air.

b) Humidity

When the humidity condition is not specified, relative humidity shall be between 45 % RH and 85 % RH.

c) Precaution

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 can 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

The measuring instruments and equipment shall be the same as listed in IEC 60747-5-6:2016, 6.1.2.

4.2 Radiative current (I_{rad}) measurement

4.2.1 Purpose

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

4.2.2 Measurement procedure

The measurement procedure is as follows.

a) Measure the IQE (η_{IQE}) and the forward voltage (V_F) at a specified forward current (I_F).

b) Calculate the radiative current by multiplying the IQE with the forward current, i.e.,

$$I_{rad} = \eta_{IQE} I_F$$

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

NOTE 2 The measurement of the IQE at a specified current is listed in IEC 60747-5-9 and IEC 60747-5-10.

4.3 Nonradiative current (I_{nonrad}) measurement

4.3.1 Purpose

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

4.3.2 Measurement procedure

The measurement procedure is as follows.

Calculate the nonradiative current by using the following formula:

$$I_{nonrad} = I_F - I_{rad} .$$