IEC 60747-5-14

Edition 1.0 2022-03

INTERNATIONAL STANDARD

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Semiconductor devices –
Part 5-14: Optoelectronic devices – Light emitting diodes – Test method of the surface temperature based on the thermoreflectance method

IEC 60747-5-14:2022-03(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.080.99

ISBN 978-2-8322-1085-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC 60747-5-14 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

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

Draft	Report on voting
47E/773/FDIS	47E/784/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 5-14: Optoelectronic devices – Light emitting diodes – Test method of the surface temperature based on the thermoreflectance method

1 Scope

This part of IEC 60747-5 specifies the measuring method of the surface temperature of single LED die or package, based on the thermoreflectance (TR) method. TR is the effect that the reflectance of light changes with the temperature of a substance. This part measures relative change in the reflectance of light from a metal film deposited nearby on the metallurgical pn junction as the relative change in the LED junction temperature. The surface temperature can be approximated as the junction temperature when the thermal resistance effect between the metal surface and the pn junction is negligibly small.

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 60747-5-6:2021, *Semiconductor devices – Part 5-6: Optoelectronic devices – Light emitting diodes*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 60747-5-6 and the following 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 Terms and definitions

3.1.1
sample
measurement object consisting of an LED die and a metal (or any reflective) film formed on the surface of the LED die or package

3.1.2
ambient temperature
T_a
temperature at or near the metal film specified for the purpose of the TR method

3.1.3
beam diameter
light beam diameter for TR measurement applied to the thin metal film

Note 1 to entry: If the light intensity has a Gaussian distribution, the diameter of the circle represented by the envelope of $1/e^2$ of the maximum intensity.

3.1.4
standard metal film
metal bulk film whose reflectance of light is specified for the purpose of calibrating equipment or correcting measured values using the principle of the TR method

3.1.5
thermoreflectance
effect that the reflectance of light changes with the temperature of a substance

3.1.6
thermoreflectance method
optical technique for measuring the relative change in surface reflectance ($\Delta R/R$) due to a change in local surface temperature (ΔT) of a particular sample

Note 1 to entry: As the temperature of the sample changes, so does the index of refraction, and hence the reflectance. In general, the linear relationship between the change in reflectance and the change in temperature can be approximated.

3.1.7
thermoreflectance coefficient
C_{TR}
first order relationship between the change in the reflectance and the change in temperature

Note 1 to entry: For most metals and semiconductor materials of interest, the relationship between the relative change in reflectance and the change in temperature is linear over a measured temperature range and is quantified by the thermoreflectance coefficient, C_{TR} (K^{-1}).

$$C_{TR} = \frac{1}{R}\frac{\partial R}{\partial T}$$

where R is the reflectance of light at a surface temperature T_s. For the light normally incident on the sample, the thermoreflectance coefficient can be used to express the reflectance light intensity as follows:

$$C_{TR} = \frac{1}{R}\frac{\partial R}{\partial T} = \frac{1}{I_n}\frac{\partial I_n}{\partial T}$$

where I_n is the normally reflected intensity at a surface temperature T_s.

3.1.8
surface temperature
T_s
temperature of the material, such as the bulk metal film, at the point where the light reflectance is measured based on the TR method

3.1.9
reference temperature
T_0
surface temperature of the sample when the reflectance change is zero

Note 1 to entry: As the reference temperature, the ambient temperature of the sample in thermal equilibrium is used.

3.1.10
junction temperature
T_j
temperature of the semiconductor pn junction of the LED die

Note 1 to entry: The junction temperature is in principle different from the surface temperature. The junction temperature is in general approximated by the surface temperature. If necessary, it can be more accurately obtained by using the power dissipation and thermal resistance between the surface of the sample and the pn junction.

Note 2 to entry: The measurement of the junction temperature and thermal resistance are listed in 6.7 of IEC 60747-5-6:2021.

3.2 Abbreviated terms

LED light emitting diode

TR thermoreflectance

4 Measuring methods

4.1 Basic requirements

4.1.1 Measuring conditions

a) Temperature

If not specified, measurements shall be made at an ambient (T_a) of (25 ± 3) °C in a condition of natural convection.

b) Humidity

When humidity condition is not specified, relative humidity shall be between 25 % RH and 75 % 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 steady-state condition. Thermal steady-state condition 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 listed in 6.1.2 of IEC 60747-5-6:2021.

4.2 Purpose

To measure the surface temperature at an operating current of the LED die or package by using a noncontact technique of the TR method [1][1]. The TR method is especially useful in the following cases:

a) the die size is very small, like a micro LED, so even small probe electrical signals can disturb the actual junction temperature value;

b) the linear relationships between the junction voltage and the forward voltage are not guaranteed, such as very high injection current density for high radiant power and high operating temperature.

[1] Numbers in square brackets refer to the Bibliography.

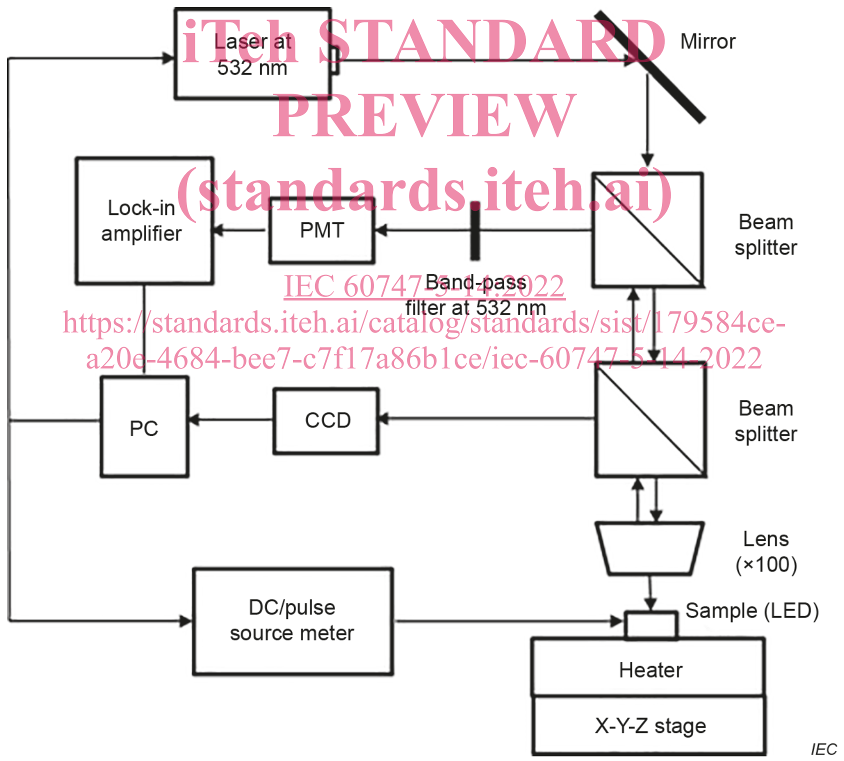
4.3 Measurement

4.3.1 Measurement setup

4.3.1.1 General

All the test should be performed under the well certified and defined conditions to avoid any external disturbances. The LED sample at a constant ambient temperature is driven by forward current and the TR measurement is performed under steady state. Basic characteristic measurements of the LED sample such as current, voltage, spectrum, and radiant power are the same as listed in IEC 60747-5-6:2021.

Figure 1 shows a configuration example of an apparatus using the principle of the TR method. The sample is placed on a hot-plate with good temperature control that is large enough for the sample size. As a light source, a 532 nm laser, which is most sensitive to Au metal, is used. The laser beam is focused on a point as close as possible, within a recommended value of 500 µm, to the region where heat is generated in the LED die so that the thermal resistance between them can be ignored. A photomultiplier tube (PMT) is used as the light-receiving element, and the sensitivity of reflectance measurement is increased by using a lock-in amplifier synchronized with the laser beam pulse. The configuration shown in this figure is the most basic, and a multiple of configurations can be adopted depending on the type of light source or detector used.



Key

CCD charge-coupled device

PMT photomultiplier tube

PC personal computer

Figure 1 – Schematic diagram of the TR setup

4.3.1.2 Light source

A laser or a LED can be used as the light source for the TR measurement. Continuous or pulsed light is used to measure the temperature with the TR method. Periodic light pulses combined with a lock-in amplifier are preferred to reduce reflectance measurement errors. The radiant power of the light source represents the average value. The radiant power density of the light on the surface of the metal film is selected from the viewpoints of suppressing the temperature rise due to light absorption during the reflectance measurement and obtaining a sufficient signal-to-noise ratio.

4.3.1.3 Detector

A photodetector having sensitivity to the wavelength of the light source for temperature measurement is used. The photomultiplier tube (PMT) in the spectral range can be used from ultraviolet to near-infrared.

4.3.1.4 Temperature heating system

The sample is placed in a thermal chamber or on a hot plate operating at a constant ambient temperature. As a result, the sample without current injection is in thermal equilibrium with ambient temperature.

4.3.2 Measurement principle

4.3.2.1 General

A LED sample with an exposed metal film, the C_{TR} value of the metal film, the reference temperature T_0, and the reflectance R from the metal film at the reference temperature are investigated before applying the TR method.

By increasing the forward current to the LED die at a constant ambient temperature T_a, the surface temperature T_s of the metal film rises and arrives at the steady state. The heat spreads and the temperature distribution in the metal surface becomes uniform. The reflectance R of the surface of the metal film changes with a change in temperature due to the thermoreflectance effect. Therefore, by measuring the relative change in surface reflectance ($\Delta R/R$) of the light beam and using the reference temperature, it is possible to measure absolute values of the surface temperature as a function of forward current. Finally, the junction temperature is approximated by the same value of the surface temperature. Figure 2 schematically illustrates how the thermoreflectance coefficient is measured and utilized to obtain the surface temperature and the junction temperature. Condition for approximating the measured surface temperature to the junction temperature will be given in 4.3.2.6.