IEC 62830-2

Edition 1.0 2017-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Semiconductor devices for energy harvesting and generation –
Part 2: Thermo power based thermoelectric energy harvesting

Dispositifs à semiconducteurs – Dispositifs à semiconducteurs pour recupération et production d'énergie –
Partie 2: Récupération d'énergie thermoélectrique basée sur la puissance thermoélectrique

IEC 62830-2:2017-01(en-fr)

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 62830-2

Edition 1.0 2017-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Semiconductor devices for energy harvesting and generation – Part 2: Thermo power based thermoelectric energy harvesting

Dispositifs à semiconducteurs – Dispositifs à semiconducteurs pour recupération et production d'énergie – Partie 2: Récupération d'énergie thermoélectrique basée sur la puissance thermoélectrique

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.080.99 ISBN 978-2-8322-3830-1

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – SEMICONDUCTOR DEVICES FOR ENERGY HARVESTING AND GENERATION –

Part 2: Thermo power based thermoelectric energy harvesting

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62830-2 has been prepared by IEC technical committee 47: Semiconductor devices.

The text of this standard is based on the following documents:

FDIS	Report on voting
47/2329/FDIS	47/2352/RVD

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 the parts in the IEC 62830 series, published under the general title *Semiconductor devices – Semiconductor devices for energy harvesting and generation*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR DEVICES – SEMICONDUCTOR DEVICES FOR ENERGY HARVESTING AND GENERATION –

Part 2: Thermo power based thermoelectric energy harvesting

1 Scope

This part of IEC 62830 describes procedures and definitions for measuring the thermo power of thin films used in micro-scale thermoelectric energy generators, micro heaters and micro coolers. This part of IEC 62830 specifies the methods of tests and the characteristic parameters of the thermoelectric properties of wire, bulk and thin films which have a thickness of less than 5 µm and energy harvesting devices that have thermoelectric thin films, in order to accurately evaluate their performance and practical uses. This part of IEC 62830 is applicable to energy harvesting devices for consumer, general industries, military and aerospace applications without any limitations of device technology and size.

2 Normative references

There are no normative references in this document.

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
Seebeck coefficient
S
magnitude of an induced thermoelectric voltage in response to a temperature difference across a material, and the entropy per charge carrier in the material

3.2
thermal conductivity
k
at a point fixed in a medium with a temperature field, scalar quantity λ characterizing the ability of the medium to transmit heat through a surface element containing that point: φ=-k grad T, where φ is the density of heat flow rate and T is thermodynamic temperature

Note 1 to entry: In an anisotropic medium, thermal conductivity is a tensor quantity.

Note 2 to entry: The coherent SI unit of thermal conductivity is watt per metre kelvin, W/(m·K).

[SOURCE: IEC 60050-113:2011, 113-04-38]

3.3
electrical conductivity
specific conductance
σ
value of a material’s ability to conduct an electrical current

3.4
<thermoelectric energy harvesting> figure of merit

Z

characteristic value of thermoelectric films given by the convolution of electrical conductivity and the square of the Seebeck coefficient divided by thermal conductivity

4 Testing methods

4.1 General

It is indispensable to measure the thermo-power to establish the thermoelectric devices. The electrical resistivity and the thermopower shall be measured in order to define the thermoelectric properties of the materials used for fabrication of thermoelectric devices. Generally to measure these values the materials should be investigated under temperature from between 3 K and 300 K. There are two types of measuring methods for thermo-power measurement. The first is the integral method and the other is the differential method. In case of measuring the electrical conductance the electrical resistivity is to be measured and the reciprocal number of the measured value is to be used.A four-point proof method is typically used in electrical resistivity. When this method is used, the total voltage drop can be measured by the sum of resistive voltage and Seebeck voltage. To obtain resistive voltage without the Seebeck-induced voltage, very fast switching DC or AC measurement is needed to measure the electrical resistivity. In addition, the sample will be prepared of a wire type which has a diameter under 200 μm and thin films which have been deposited onto the silicon substrate with a 100 nanometer insulating layer.

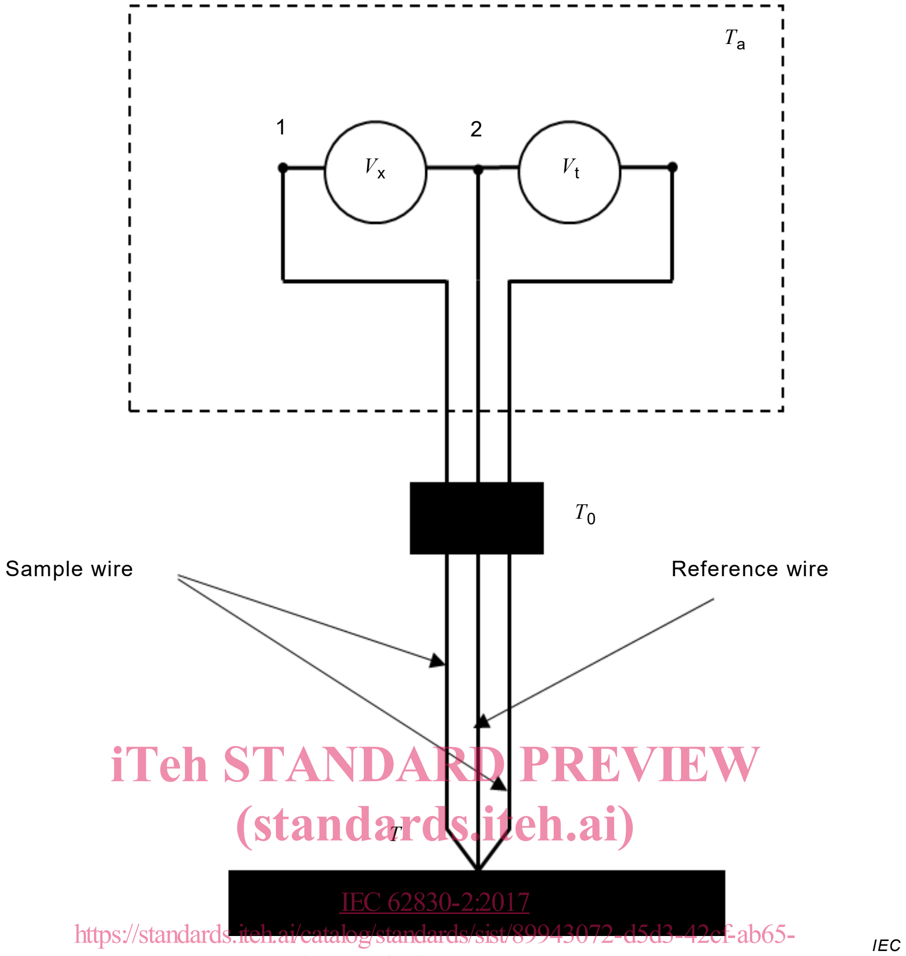
4.2 Thermo-power measurement

4.2.1 Integral method

4.2.1.1 General

The integral method is a very simple method of obtaining the thermo-power value for thermoelectric materials. The generated voltage change between the reference material and sample material is used for the calculation of the thermo-power value of the materials. In this method the materials shall be fabricated in wire form to make a thermocouple form. The third thermocouple can be attached to the hot junction of the reference and sample wire to measure the temperature of the junction.

The schematic diagram of the integral method to measure the thermo-power of thermoelectric materials is shown in Figure 1.



Key

T: temperature to be measured

T_0: temperature of cold junction

V_x, V_t: voltmeter which can measure the voltage drop

T_a: temperature of ambient

Figure 1 – Schematic diagram of integral method for measurement of the thermo-power of thermoelectric materials

At the thermocouple of the measured material and the reference the potential difference can be measured using equations (1) and (2).

$$\Delta V = -\int_{term1}^{term2} E dl = -\int_{term1}^{term2} \alpha \nabla T dl \qquad (1)$$

Or

$$\Delta V = -\left(\int_{T_a}^{T_0}\alpha_{Cu} dT + \int_{T_0}^{T}\alpha_x dT + \int_{T}^{T_0}\alpha_{ref} dT + \int_{T_0}^{T_a}\alpha_{Cu} dT\right) = -\int_{T_0}^{T_a}\left(\alpha_x - \alpha_{ref}\right)dT \qquad (2)$$

where T_0 is temperature of cold junction of the thermocouples and T_a is usually absolute value of T_0 = 274,15 K. As shown in the equation (3), the numerical differentiation of the measured voltage change of the thermocouple has been derived.

$$\frac{d\Delta V}{dT} = -\left(\alpha_x - \alpha_{ref}\right)_T \qquad (3)$$

Finally the value of the sample wire's thermo-power is obtained using equation (4) when the thermo-power of the reference material has been already known.

$$\alpha_x(T) = -\left(\frac{d\Delta V}{dT}\right)_T + \alpha_{ref}(T) \qquad (4)$$

4.2.1.2 Test procedure

a) Form a wire of sample material using any kind of method to make a wire form.

b) Join the sample material wire and reference wire for using hot junction.

c) Attach another third wire for measuring the temperature of hot junction.

d) Place one voltmeter between the third wire and reference wire.

e) Place the other voltmeter between the reference wire and the sample wire

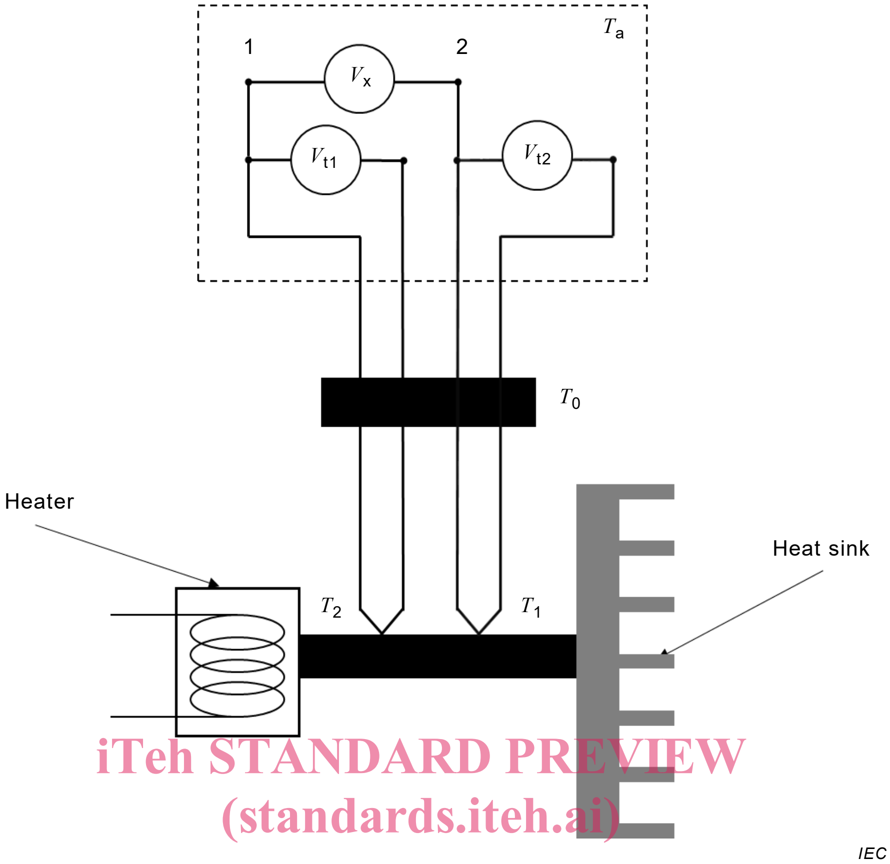
f) Read the voltage difference between the sample and reference wire.

g) Calculate the thermo-power using equation (4).

4.2.2 Differential method

4.2.2.1 General

The differential method is measuring two points of material to be measured. The potential difference can be also measured simultaneously when the net current through the sample is zero. At that time the electrical field in the measuring sample is given by $E = \alpha \Delta T$ which is due to thermo-power. In Figure 2 the schematic diagram of the differential method for measuring thermo-power is shown.



Key

T_1, T_2: temperature to be measured T_a: temperature of ambient
T_0: temperature of cold junction
V_x, V_{t1}, V_{t2}: voltmeter which can measure the voltage drop

Figure 2 – Schematic diagram of the differential method for measuring the thermo-power

When the thermocouple wires and the sample are joined homogeneously, measuring errors can be minimized and equations (5), (6) and (7) can be used for calculation of the thermo-power of the materials. Under these conditions potential difference is given by the equation.

$$\Delta V = -\left(\int_{T_a}^{T_0} \alpha_{Cu} dT + \int_{T_0}^{T_1} \alpha_{ref}^{1} dT + \int_{T_1}^{T_2} \alpha_x dT + \int_{T_2}^{T_0} \alpha_{ref}^{2} dT + \int_{T_0}^{T_a} \alpha_{Cu} dT\right) \tag{5}$$

For a homogeneous reference wire the second and the fourth integral terms can be merged and the equation (5) can be modified into a more simple equation (6).

$$\Delta V = -\int_{T_1}^{T_2} \left(\alpha_x - \alpha_{ref}\right) dT \tag{6}$$

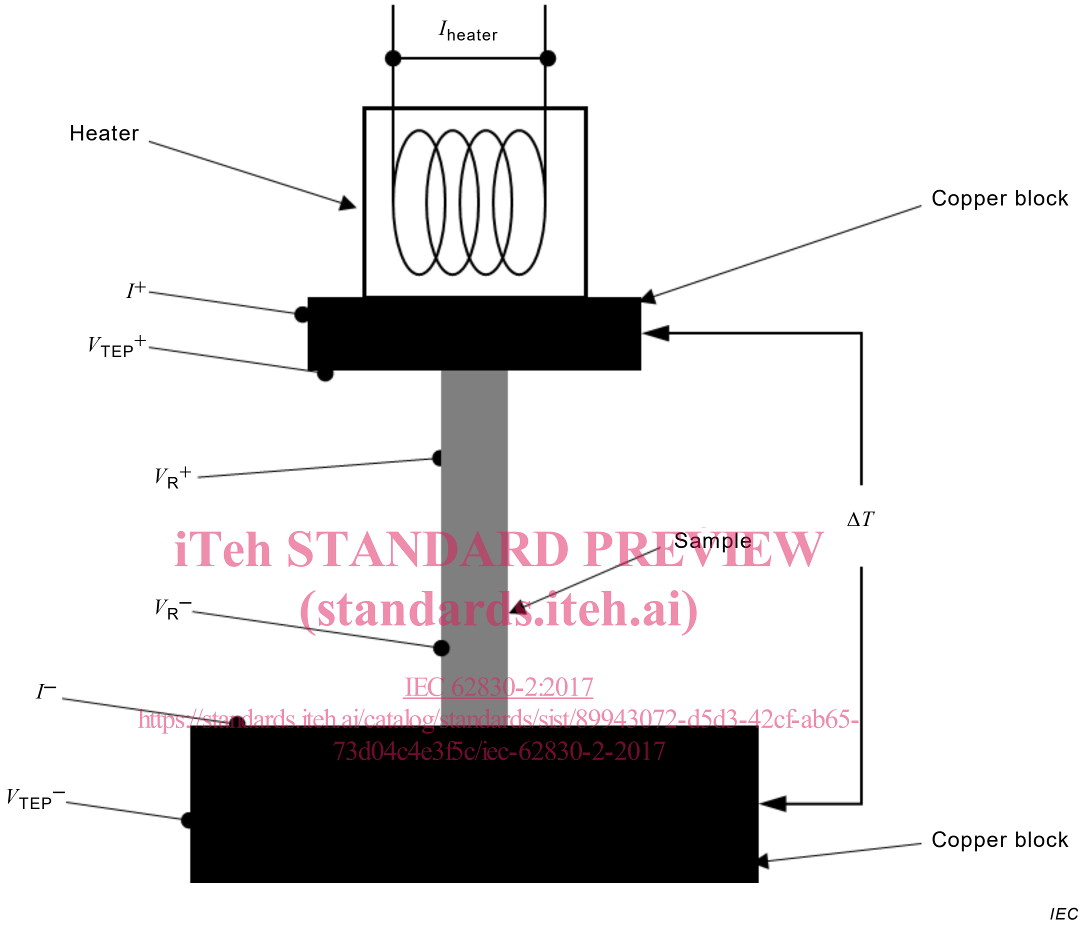
If the temperature difference is only given by the difference between point 1 and point 2, the final simplified form is given as shown in equation (7).

$$\alpha_x\left(T_{av}\right) = -\frac{\Delta V}{\Delta T} + \alpha_{ref}\left(T_{av}\right) \tag{7}$$

when the T_{av} is given by the half of the sum of the T_1 and T_2.

4.2.2.2 Test Procedure

The diagram of the setup for the measurement of the resistivity and Seebeck coefficient of bulk materials using the differential method is shown in Figure 3.



Key

ΔT:	temperature difference	I_{heater}:	current for heater
I^+:	positive current	I^-:	negative current
V_{R+}:	resistive positive voltage	V_{R-}:	resistive negative voltage
V_{TEP+}:	thermoelectric positive voltage	V_{TEP-}:	thermoelectric negative voltage

Figure 3 – Diagram of the setup for measuring electrical resistivity and Seebeck coefficient using differential method

In thermoelectric materials the Seebeck coefficient is relatively larger than non-thermoelectric materials. So the total voltage across the sample shall be the summation of the Seebeck voltage and the resistive or IR voltage which is given by the equation (8).

$$V_{total} = V_{IR} + \alpha \Delta T \quad (8)$$

Generally the resistive voltage has a negligible effect on the Seebeck voltage portion of the total voltage. Therefore to minimize the Seebeck effect contribution to measure the IR voltage, the measurement process should be processed very fast, for example in 2 seconds or 3 seconds. By switching the current direction the Seebeck voltage can be cancelled out using the averaging technique, as shown in equation (9).