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INTERNATIONAL STANDARD

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Semiconductor devices – Micro-electromechanical devices – Part 42: Measurement methods of electro-mechanical conversion characteristics of piezoelectric MEMS cantilever

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FOREWORD

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

Draft	Report on voting
47F/414/FDIS	47F/417/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.

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 42: Measurement methods of electro-mechanical conversion characteristics of piezoelectric MEMS cantilever

1 Scope

This part of IEC 62047 specifies measuring methods of electro-mechanical conversion characteristics of piezoelectric thin film on microcantilever, which is typical structure of actual micro sensors and micro actuators. In order to obtain actual and precise piezoelectric coefficient of the piezoelectric thin films with microdevice structures, and this document reports the schema to determine the characteristic parameters for consumer, industry or any other applications of piezoelectric devices. This document applies to piezoelectric thin films on microcantilever fabricated by MEMS process.

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 database for use in standardization at the following addresses:

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

3.1
unimorph microcantilever
micro-scale cantilever composed of piezoelectric thin film and non-piezoelectric material, typically thin silicon layer

Note 1 to entry: The piezoelectric thin films are deposited on bottom electrode. Top electrodes are prepared on the piezoelectric thin films and input voltage are applied between top and bottom electrodes. Platinum is often used as top and bottom electrodes for piezoelectric MEMS devices. The thickness of both top and bottom electrodes should be thinner than that of piezoelectric thin film and non-piezoelectric layer of microcantilever. In case of direct piezoelectric measurements, output signal is measured between bottom electrode and sensing top electrode as described in 5.4.

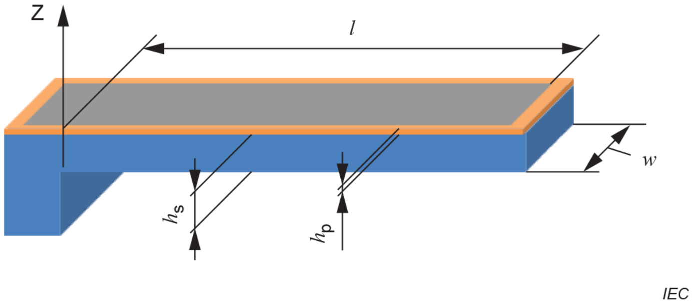
3.2
converse transverse piezoelectric coefficient
transverse piezoelectric coefficient of the piezoelectric thin film calculated from strain or stress caused by electric field or voltage

3.3
direct transverse piezoelectric coefficient
transverse piezoelectric coefficient of the piezoelectric thin film calculated from generated charge or voltage caused by strain or stress

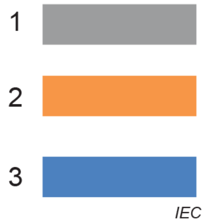
4 Test bed of MEMS piezoelectric thin film

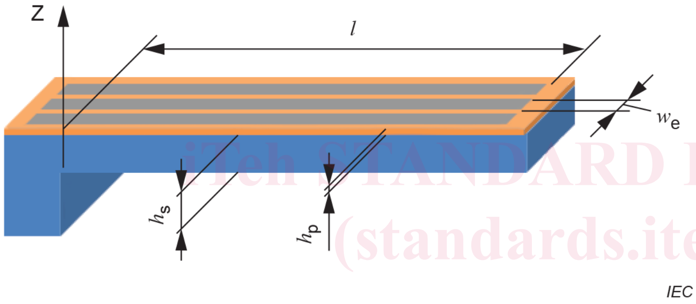
4.1 General

These measuring methods of the transverse piezoelectric properties apply to the unimorph microcantilevers.



a) converse piezoelectric effect





b) direct piezoelectric effect

Key

1 electrode

2 piezoelectric thin film

3 non-piezoelectric layer

Figure 1 – Test bed of piezoelectric MEMS unimorph cantilever

Symbols and designations of test bed are given in Table 1.

Table 1 – Symbols and designations of test bed

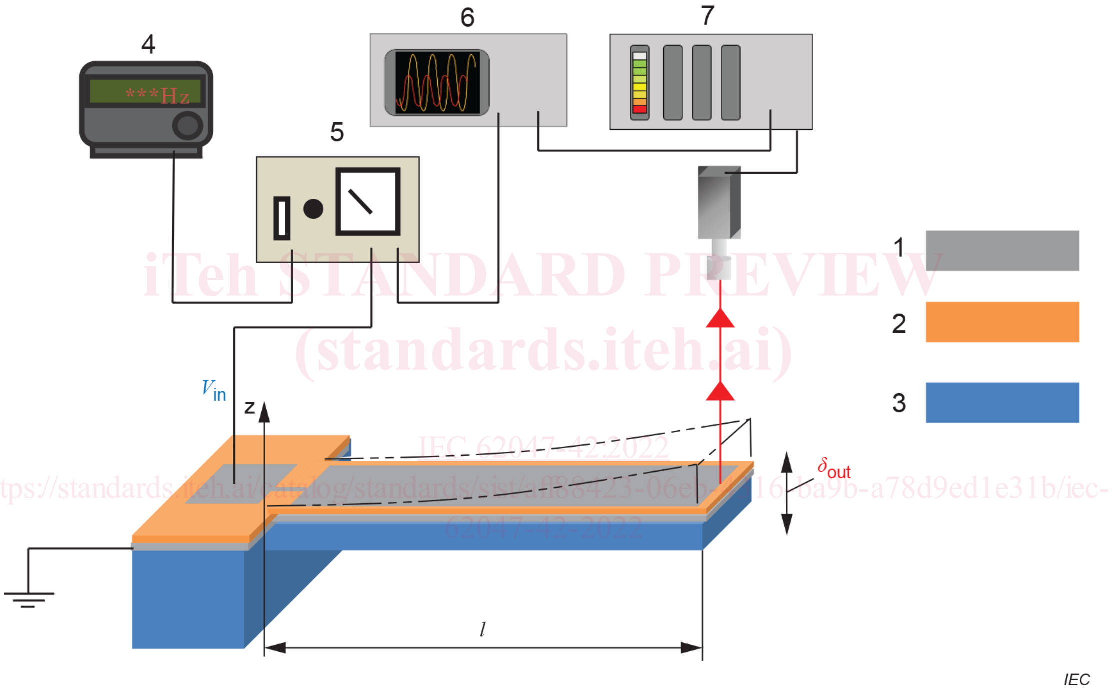
Kind of properties	Symbol	Unit	Designation
Dimension of cantilever specimen	l	m	length of microcantilever
	w	m	width of microcantilever
	w_e	m	width of sensing top electrode
	h_s	m	thickness of non-piezoelectric layer
	h_p	m	thickness of piezoelectric thin film
Electro-mechanical conversion properties	$e_{31,\mathrm{f}}$	C/m^2	effective transverse piezoelectric coefficient
	$e^\mathrm{d}{}_{31,\mathrm{f}}$	C/m^2	effective transverse piezoelectric coefficient (direct effect)
	$e^\mathrm{c}{}_{31,\mathrm{f}}$	N/Vm	effective transverse piezoelectric coefficient (converse effect)
	$e^\mathrm{c}{}_{31,\mathrm{f}}(V_{\mathrm{in},0})$	N/Vm	extrapolated effective transverse piezoelectric coefficient at 0V (converse effect)
	$e^\mathrm{c}{}_{31,\mathrm{f}}(V_{\mathrm{in,min}})$	N/Vm	minimum effective transverse piezoelectric coefficient (converse effect at the lowest V_in)
	$e^\mathrm{c}{}_{31,\mathrm{f}}(V_{\mathrm{in,max}})$	N/Vm	maximum effective transverse piezoelectric coefficient (converse effect)
	d_{31}	m/V	transverse piezoelectric coefficient (d-form)
Electrical properties	C	F	capacitance between sensing top electrode and bottom electrode
	Q_out	C	output electric charge
	V_in	V	input peak-to-peak voltage
	$tan\ \delta$		dielectric loss
	ω	rad/s	angular frequency
Mechanical properties	E	N/m^2	Young's modulus of microcantilever
	I	m^4	area moment of inertia of microcantilever
	ρ	kg/m^3	density of microcantilever
	D	m	tip displacement at x1
	E_s	N/m^2	Young's modulus of non-piezoelectric layer
	ν_s		Poisson's ratio of non-piezoelectric layer
	E_p	N/m^2	Young's modulus of piezoelectric thin film
	ν_p		Poisson's ratio of piezoelectric layer
	y_c	m	position of neutral plane of the unimorph cantilever from the bottom
	$s^\mathrm{E}{}_{11}$, $s^\mathrm{E}{}_{12}$	m^2/N	elastic compliances of piezoelectric thin film

4.2 Functional blocks and components

4.2.1 General

Figure 1 provides typical structure of the specimens consisted of piezoelectric unimorph microcantilever fabricated from a PZT (lead zirconate titanate (Pb[Zr(x)Ti(1-x)]O3)) thin film on a Si(Silicon) or SOI (Silicon On Insulator) wafer. For the converse piezoelectric measurements, the surface of the unimorph microcantilever is covered by single top electrode where actuation voltage is applied (Figure 1 a)). Width of the top electrode is almost same as that of microcantilever. On the other hand, for direct piezoelectric measurements, top electrode is divided into three parts so that the bending vibration is generated by applying actuation voltage on two actuation electrodes, and simultaneously output voltage or charge by direct piezoelectric effect is measured from the centre sensing electrode (Figure 1 b)).

Details of the functional blocks or components named as the keys are provided in 4.2.2 to 4.2.4.



Key

1	electrode	5	power amplifier
2	piezoelectric thin film	6	oscilloscope
3	non-piezoelectric layer	7	laser Doppler vibrometer
4	function generator		

Figure 2 – Setup for measurement of converse piezoelectric effect