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INTERNATIONAL STANDARD

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Semiconductor devices – Micro-electromechanical devices – Part 48: Test method for determining solution concentration by optical absorption using MEMS fluidic device

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

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

Draft	Report on voting
47F/466/FDIS	47F/472/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/publications.

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- withdrawn, or
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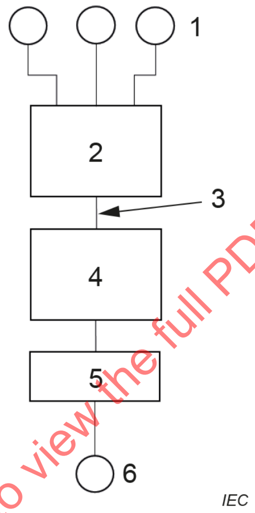
INTRODUCTION

A MEMS fluidic device is one of the key devices in MEMS technologies, including bio-MEMS, chemical MEMS, and micro TAS (total analytical system). A MEMS fluidic device, in general, consists of several micro components such as inlet ports for injection of a filtered sample and reagents to induce a sample to have the optical absorption at specific wavelength, a microfluidic mixer for physical mixing, a micro-reactor for chemical or biological reaction, a detection area for determining the concentration of solution using optical source and detector from the outside, as well as outlet ports for waste-out as shown in Figure 1. All components in a MEMS fluidic device are connected with microfluidic channels. In case there is a synthesizing solution with absorption at a specific wavelength in a MEMS fluidic device, it is possible to determine the concentration by using an absorption method at specific absorption wavelength based on the Beer-Lambert law [1][1]. MEMS fluidic devices are more cost-effective than conventional analysis tools and methods since expensive reagents and human power are used less and in-situ monitoring is enabled.



Key

1 inlet ports

2 microfluidic mixer

3 microfluidic channel

4 micro-reactor

5 detection area

6 outlet port

Figure 1 – Schematic drawing of micro components in a MEMS fluidic device (top view)

1 Numbers in square brackets refer to the Bibliography.

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 48: Test method for determining solution concentration by optical absorption using MEMS fluidic device

1 Scope

This part of IEC 62047 specifies the requirements and testing method to determine the solution concentration by optical absorption using MEMS fluidic device.

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 terminology databases 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
microfluidic mixer
MEMS fluidic device for mixing more than two liquid samples in microfluidic channel and chamber

3.2
MEMS fluidic channel
microfluidic channel
channel in sub-micron or micron dimension to deliver liquid or gas, fabricated usually by micromachining or MEMS techniques

4 Test method

4.1 General

4.1.1 Principle of the absorption method

The principle of the absorption method for determining the concentration of a solution is based on the Beer-Lambert law. As shown in Figure 2, Beer-Lambert law relates the optical attenuation of a physical material containing a single attenuating species of uniform concentration to the optical path length through the sample and absorptivity of the species with the following Formula (1):

$$A = -\log T = \log(1/T) = a \cdot b \cdot c \qquad (1)$$

where:

A is the absorbance, expressed as a ratio;

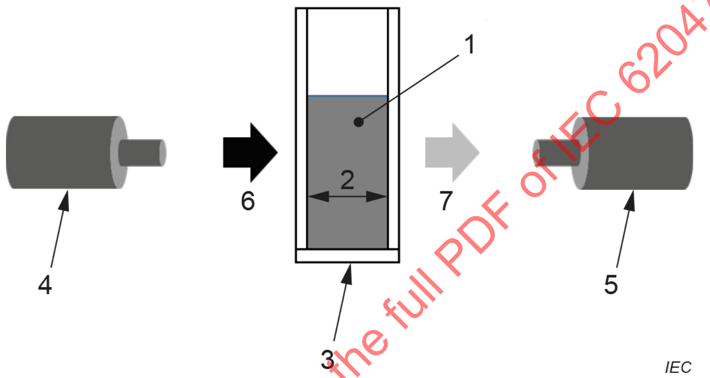
T is the transmittance, expressed as the ratio of transmitted intensity to the incident intensity = I/I_0;

a is the molar absorption coefficient, expressed in per molar concentration per optical path length (in $M^{-1}cm^{-1}$);

b is the optical path length (in cm);

c is the molar concentration (in M).

Based on the Beer-Lambert law, the molar concentration, c (in M), is calculated as a function of the molar absorption coefficient, a (in $M^{-1}cm^{-1}$), optical path length b (in cm), and absorbance A (ratio), with these parameters being given or measured at a specified temperature (in °C) for the MEMS fluidic device.



Key

1 specimen (solution) with molar concentration, c

2 optical path length, b

3 cuvette

4 optical source (laser)

5 optical detector (photodiode)

6 incident intensity, I_0

7 transmitted intensity, I

Figure 2 – Optical absorption method for determining the concentration of the solution using a conventional cuvette (side view)

Figure 3 presents a graph where the x-axis is the concentration c (in M) and the y-axis is the absorbance A. For a molar concentration under 10^{-3} M, Formula (1) is linear.

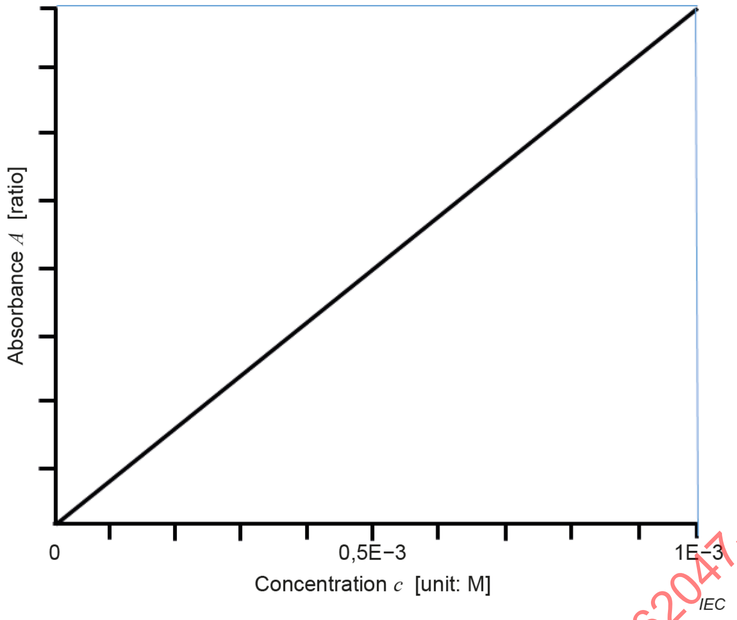


Figure 3 – Schematic graph with the x-axis as the concentration, *c* and the y-axis as absorbance *A*

4.1.2 Molar absorption coefficient, *a*

The molar absorption coefficient or molar attenuation (or extinction) coefficient is a measurement of how strongly a chemical species absorbs, and thereby attenuates, light at a given wavelength. The unit of molar absorption coefficient is $M^{-1}cm^{-1}$ [1]. The molar absorption coefficient is calculated using $a = A/bc$, derived from Formula (1) in advance by measuring the intensity of the incident and transmitted light for a solution whose the concentration, c, is known. The calculated molar absorption coefficient shall be recorded in the test report.

4.1.3 Optical path length, *b*

The optical path length is the length for the incident light to pass through the solution in the MEMS fluidic channel. The unit of optical path length is cm. The measured optical path length shall be recorded in the test report.

4.1.4 Absorbance, *A*

The absorbance of the solution is related to the transmittance, the ratio of transmitted intensity to the incident intensity in Formula (1). The measured absorbance shall be recorded in the test report.

4.1.5 Surface temperature of MEMS fluidic device

Because the solution concentration depends on the surface temperature of the MEMS fluidic device, the measured surface temperature of the MEMS fluidic device shall be recorded in the test report.

4.1.6 Molar concentration, *c*

Molar concentration is a measure of the concentration of a chemical species, in particular of a solute in a solution, in terms of the amount of solution per unit volume of solution [1]. The unit of molar concentration is M. The calculated molar concentration based on Formula (1) shall be recorded in the test report.

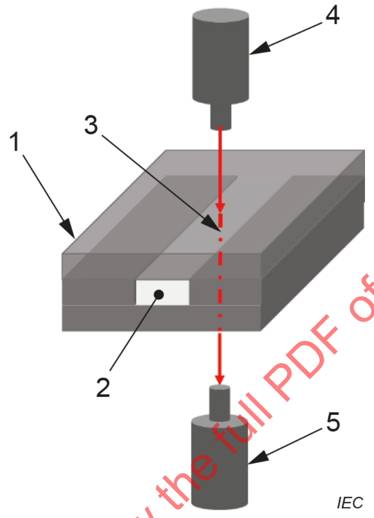
5 Test specimen

5.1.1 Test specimen

The test specimen is a liquid solution without any solid particle in the MEMS fluidic device.

5.1.2 Configuration of concentration measuring unit for test specimen

A concentration measuring unit for the test specimen consists of a MEMS fluidic device, an optical source such as laser, and an optical detector such as photodiode as shown in Figure 4. The optical source and the optical detector are aligned with the microfluidic channel in the perpendicular direction to the MEMS fluidic device.



Key

1 MEMS fluidic device

2 microfluidic channel

3 measuring location

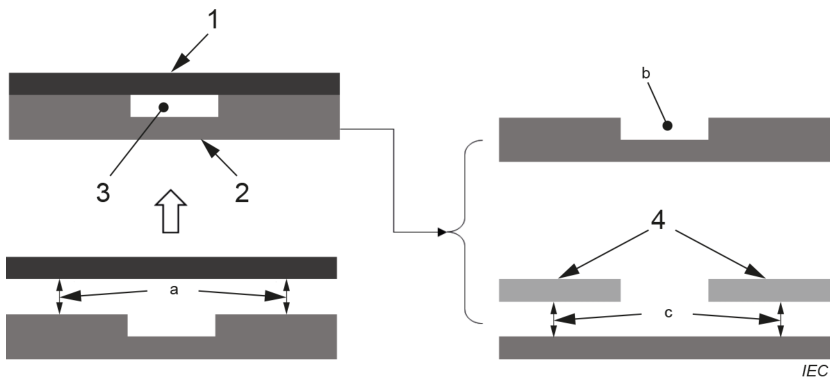
4 optical source (laser)

5 optical detector (photodiode)

Figure 4 – Schematic drawing of a concentration measuring unit for a test specimen based on a MEMS fluidic device

5.1.3 Layer stack of the MEMS fluidic device

A MEMS fluidic device for measuring the concentration of a fluid consists of a cover layer and microfluidic channel plate (see Figure 5). The microfluidic channel on the microfluidic channel plate can be machined by an etching process, moulding, hot embossing, UV embossing process or bonding an additional layer with a through-hole type channel on a plate, etc. The cover layer and microfluidic channel plate are bonded or assembled to seal the microfluidic channel (see Table 1).



Key

1 cover layer

2 microfluidic channel plate

3 microfluidic channel

4 additional layer blanked

[a] bonding or assembling

[b] machined by etching, moulding, embossing, etc

[c] bonding to form microfluidic channel

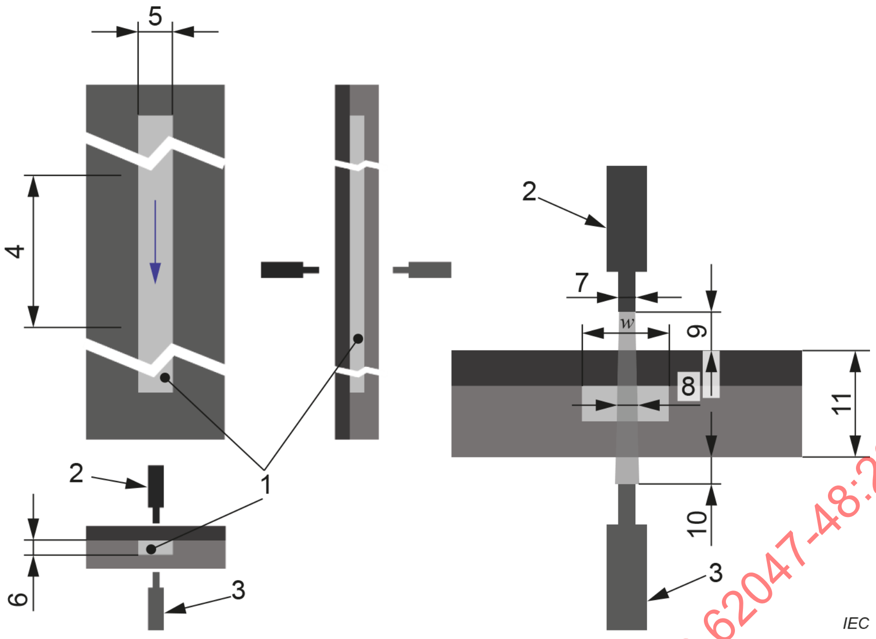
Figure 5 – Schematic structure and process for preparation of MEMS fluidic device

Table 1 – Test unit for determining solution concentration using MEMS fluidic device

	Material	Specifications
Cover layer	Transparent and bondable material, for instance glass	Nominal thickness shall be between 0,500 mm and 1 mm. The tolerance of the nominal thickness shall be ±5 %.
Microfluidic channel plate	Etchable or formable materials, for instance silicon	Nominal thickness shall be between 0,500 mm and 1 mm. The tolerance of the nominal thickness shall be ±5 %.
Bottom layer	Transparent and bondable material, for instance glass	Nominal thickness shall be between 0,500 mm and 1 mm. The tolerance of the nominal thickness shall be ±5 %.

5.1.4 Size and shape of the micro-channel

The size of the microfluidic channel shall be several hundred micro-meters in depth or width, or both. The length of the microfluidic channel shall be at least few millimetres for fully developed flow at the measuring position. The width of the microfluidic channel is larger than the spot size of the light beam from the optical source. The spot size of the light beam is defined as the area greater than 75 % of intensity for gaussian distribution of the intensity. The overall size of the measuring unit is several centimetres by several centimetres to include microfluidic channel and holding area. The configurations and dimensions for the measuring unit of a MEMS fluidic device are shown in Figure 6.



Key

1 microfluidic channel

2 fibre optic light source with laser

3 fibre optic detector with photodiode

4 length of the microfluidic channel, L

5 width of the microfluidic channel, W

6 height of the microfluidic channel, b

7 diameter of the probe of the fibre optic light source with laser or fibre optic detector with photodidie, d

8 diameter of the laser beam at measuring point, e

9 clearance between fibre optic light source and MEMS fluidic device, f

10 clearance between fibre optic detector and MEMS fluidic device, g

11 total thickness of the MEMS fluidic device, t

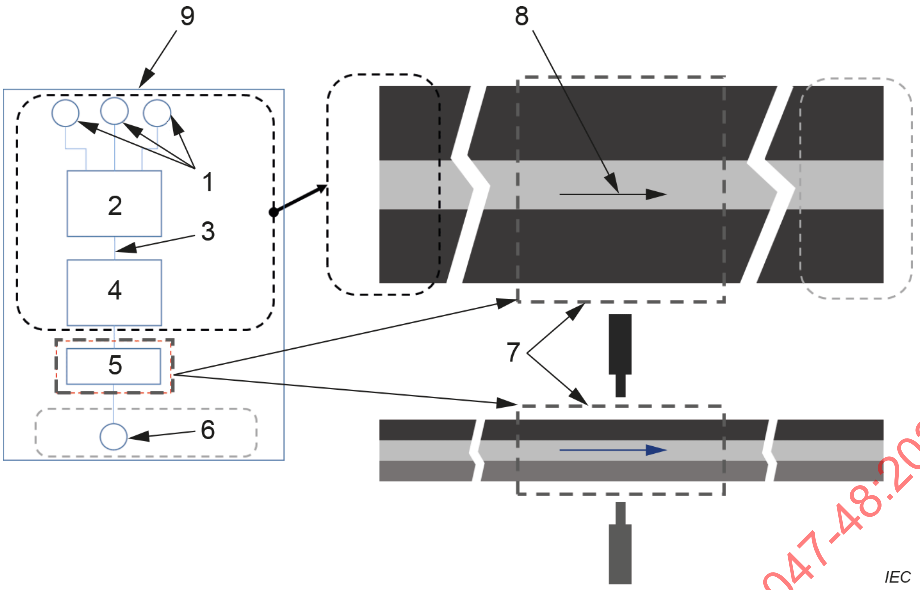
Figure 6 – Configurations and dimensions for measuring unit of MEMS fluidic device

5.1.5 Configuration of solution concentration measuring system

The microfluidic channel of the solution concentration measuring unit is connected to test fluids supplying the MEMS unit such as mixer, reactor, etc., through either on-device micro-channel or plugged-in tube.

The overall size of the MEMS fluidic device with an on-device MEMS unit shall be several centimetres by several centimetres. However, the size of the test specimen is larger so that it can be fastened into the test specimen holder of the concentration measurement equipment.

Figure 7 shows the schematic MEMS fluidic device with an on-device MEMS unit at the left-hand side (top view) and a detection part at the right-hand side (side view) as the test specimen. A laser is used as an optical source, and a photo diode matched to the laser is used as an optical detector. The key dimensions of the test specimen shall be recorded in the test report. The optical absorbance of the test specimen (solution) is measured in a stationary state in the detector part controlled by a micro syringe pump (not shown) for inlets.



Key

1 inlet ports

2 microfluidic mixer

3 microfluidic channel

4 microfluidic reactor

5 detection area

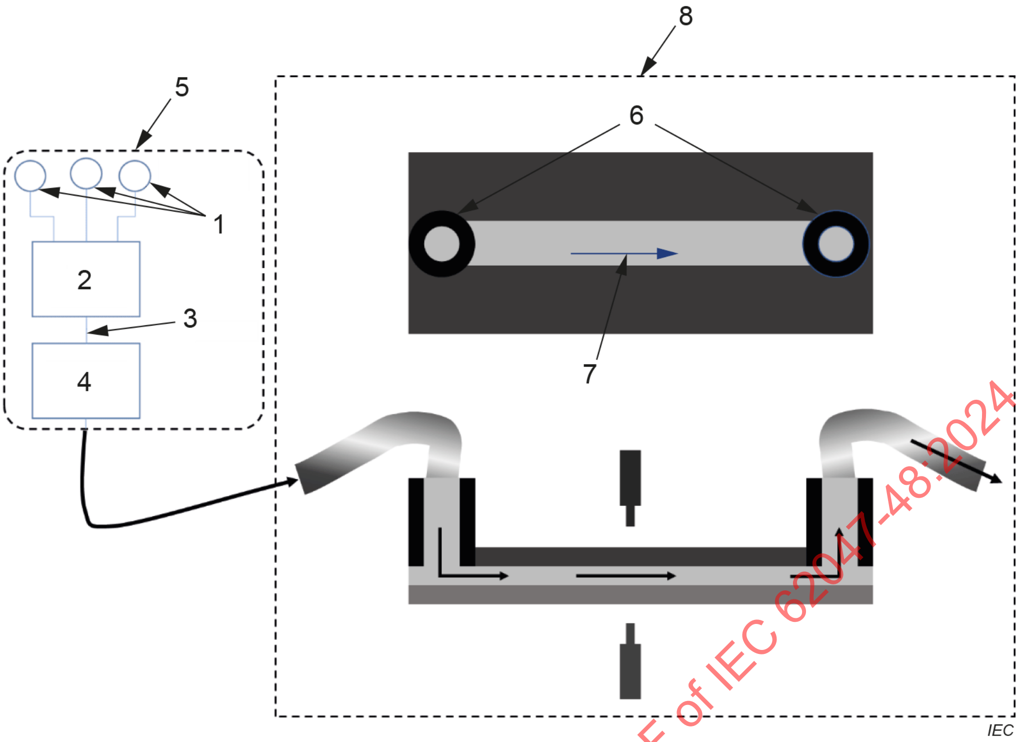
6 outlet port

7 measuring unit

8 flow direction

9 MEMS components upstream and downstream such as mixer, reactor, ports etc.

Figure 7 – Schematic drawing for a MEMS fluidic device layout with microfluidic concentration measuring unit and additional MEMS components on a single device



Key

1 inlet ports

2 microfluidic mixer

3 microfluidic channel

4 microfluidic reactor

5 MEMS fluidic device with microfluidic components

6 connecting ports

7 flow direction

8 stand-alone measuring unit

Figure 8 – Schematic drawing for stand-alone measuring unit connected with another MEMS fluidic device through tubing

An example of the concentration measurement using a MEMS fluidic device is shown Figure 8. The measurement apparatus also includes a cover because measurements shall be made at stabilized temperature. The cover is not shown in Figure 8.

5.2 Test procedure

The solution concentration is measured while the test specimen is in a stationary state controlled by a syringe pump (not shown) for inlets in the measuring unit at a specified temperature.

The test procedure is as follows:

a) Fasten the measuring unit to the holder in the horizontal direction and make the measuring unit contact with the temperature control unit.

b) Set the fibre optic laser and fibre optic detector at a distance where the incident beam can be focused mostly into the micro-channel and the transmitted beam can be focused mostly into the detector from the upper and lower surface of the measuring unit and align the fibre optic laser, microfluidic channel and fibre optic detector.

c) Set the test parameters including surface temperature and intensity of the fibre optic laser.

d) Turn on the heating element and wait until the surface temperature has reached the target temperature (target temperature ± 1 °C).

e) Prepare the reference fluids whose concentrations are known.

f) Measure the absorbance while a reference fluid is in a stationary state.

g) Make air flow through the microfluidic channel by suction from an outport to evacuate the fluid measured previously.

h) Repeat f) and g) until all reference fluids prepared are used to measure their absorbances.

i) Estimate the molar absorption coefficient a from the measured absorbances using the reference fluids.

j) Measure the absorbance of the test specimen (solution) in a stationary state controlled by a micro syringe pump (not shown) for inlets and calculate the molar concentration c.

k) Stop the concentration test.

l) Turn off the heating element.

6 Data analysis

6.1 Calculating results

a) The molar absorption coefficient a from absorbances calculated for reference fluids based on the Beer-Lambert law based on Formula (1). Using Formula (1),

   A is measured;

   a is to be calculated;

   b is known;

   c is known.

b) The molar concentration of the test specimen based on Beer-Lambert law given by Formula (1):

   A is measured;

   a is known;

   b is known;

   c is to be calculated.

6.2 Test report

The test report shall include the following items:

a) description of test specimen;

b) test information including surface temperature;

c) reference fluids

   - number of reference fluids;
   - molar concentration of each reference fluids;

d) absorbances for each reference fluid;

e) calculated molar absorption coefficient a for reference fluids;

f) absorbance for test specimen;

g) calculated molar concentration;

h) date of the tests;

i) name of organization that has done the test;

j) reference to this document.

The test report for determining solution concentration by the absorption method in the MEMS fluidic device is summarized as shown in Table 2.