IEC 62047-26

Edition 1.0 2016-01

INTERNATIONAL STANDARD

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Semiconductor devices – Micro-electromechanical devices – Part 26: Description and measurement methods for micro trench and needle structures

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 26: Description et méthodes de mesure pour structures de microtranchées et de microaiguille

IEC 62047-26:2016-01(en-fr)

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CONTENTS

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 26: Description and measurement methods for micro trench and needle structures

FOREWORD

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

FDIS	Report on voting
47F/233/FDIS	47F/239/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62047 series, published under the general title *Semiconductor devices – Micro-electromechanical devices*, can be found on the IEC website.

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

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 26: Description and measurement methods for micro trench and needle structures

1 Scope

This part of IEC 62047 specifies descriptions of trench structure and needle structure in a micrometer scale. In addition, it provides examples of measurement for the geometry of both structures. For trench structures, this standard applies to structures with a depth of 1 µm to 100 µm; walls and trenches with respective widths of 5 µm to 150 µm; and aspect ratio of 0,006 7 to 20. For needle structures, the standard applies to structures with three or four faces with a height, horizontal width and vertical width of 2 µm or larger, and with dimensions that fit inside a cube with sides of 100 µm.

This standard is applicable to the structural design of MEMS and geometrical evaluation after MEMS processes.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

None.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
trench structure
one or more rectangular structures engraved in a planar substrate, with a constant trapezoidal cross section profile

3.2
needle structure
projecting structures with a pointed tip formed of three or more faces, formed on a planar substrate with the plane of symmetry in the vertical plane

3.3
wall and trench
two or more of the trench structures arranged in parallel at regular intervals

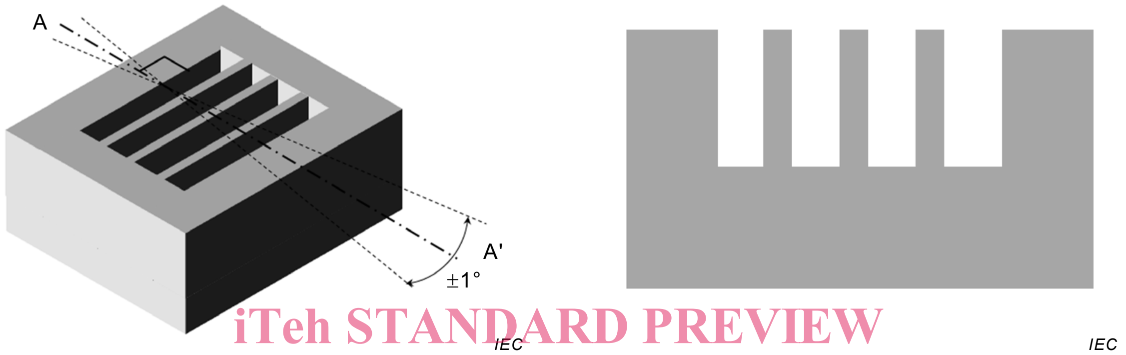
3.4
scallop
irregularity formed cyclically in the side walls after a deep-reactive ion etching (DRIE) process with repeated deposition and selective etching of polymeric passivation layer and then etching of a silicon substrate

4 Description of trench structures in a micrometer scale

4.1 General

This standard specified the method of indicating the cross-sectional geometry of trench structures with micrometer scale dimensions. Figure 1 is a diagram of the cross section required for indicating the cross-sectional geometry of trench structures in this standard. The cross-sectional geometry of trench structures is the cross-sectional shape at a line longitudinally intersecting the trench structure at right angles as viewed from the upper surface of the substrate, with an error of ±1° or less.

See Clause 6 and Annex A for the method of measuring the cross-sectional dimensions of trench structures.



a) Example of trench structure b) Cross section of trench structure at the A_A' line

Figure 1 – Schematic of example for trench structure in a micrometer scale and its cross section

4.2 Symbols and designations

The cross section of a typical trench structure is shown in Figure 2, and the symbols, designations and units used for indicating the cross section of the trench structures are listed in Table 1.

The horizontal datum line for indicating the cross section in Figure 2 is a straight line approximating the upper surface of the planar substrate. The vertical datum line is defined as a line intersecting the horizontal datum line at right angles. The trench side wall is indicated by its straight line approximation. The bottom of trench is expressed as its approximate straight or curved line. On the upper surface of the trench structure, the wall is defined as the area that is considered same as the horizontal datum line without etching, and the trench is defined as the etched area. According to these definitions, the widths of the wall and trench at the upper surface are expressed as shown in Figure 2. The trench side wall angle is defined as the angle between the horizontal datum line and approximate line of the side wall, and it is indicated with a value measured clockwise from the horizontal datum line positioned on the top of the wall to the trench side wall by the shortest distance, as shown in Figure 2. The widths of the wall and trench at the bottom of the trench are expressed by distances between intersection points with the approximate line of the side wall and approximate straight or curved line at the bottom of the trench. The depth of the trench is defined as the shortest distance from the horizontal datum line at the middle of the trench to the bottom surface of the trench.

When the trench structure is fabricated by the DRIE process with repeated deposition and selective etching of polymeric passivation layer and then etching of a silicon substrate, scallops are formed in the trench side walls after etching. Figure 3 shows a cross section of a trench structure with inverse taper side walls prepared with the DRIE etching process, including symbols for the geometry.

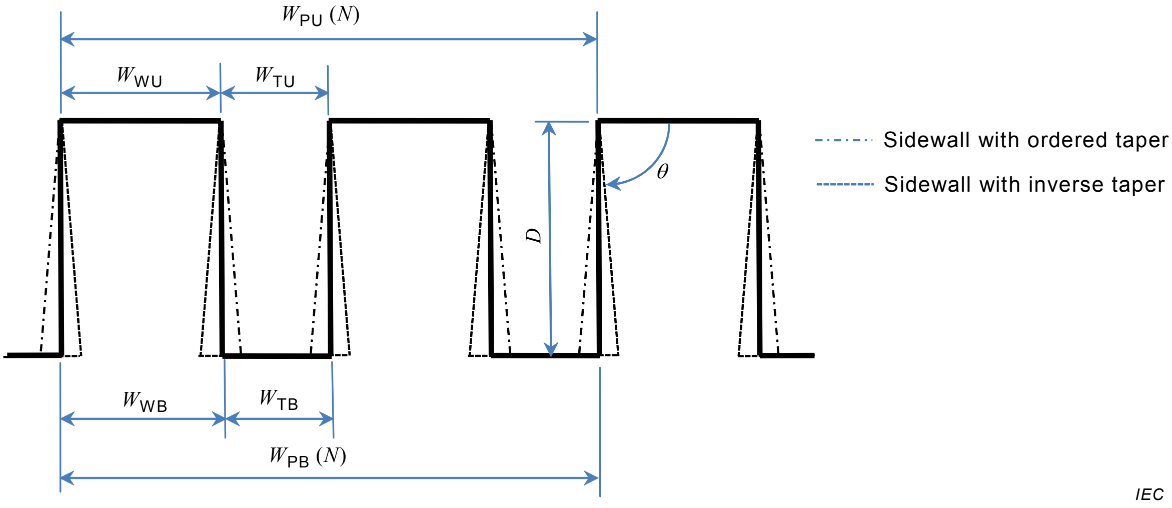


Figure 2 – Cross section of trench structure in a micrometer scale

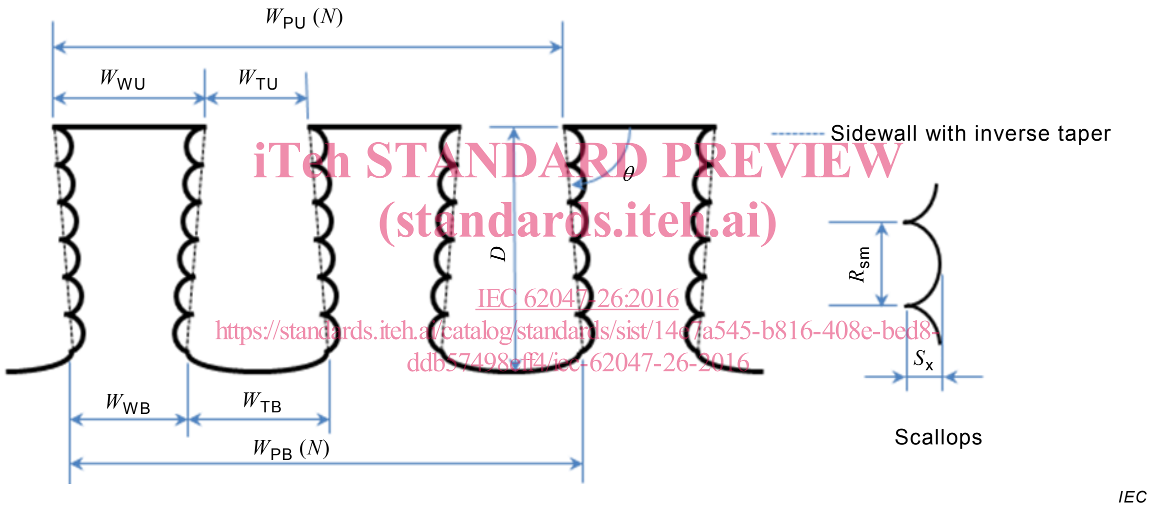


Figure 3 – Cross section of trench structure in a micrometer scale fabricated by a deep-reactive ion etching process with repeated deposition and etching of silicon

Table 1 – Symbols and designations of trench structure in a micrometer scale

Symbol	Unit	Designation
W_{WU}	µm	Width of wall part at the upper surface
W_{TU}	µm	Width of trench part at the upper surface
W_{WB}	µm	Width of wall part at the bottom of trench
W_{TB}	µm	Width of trench part at the bottom of trench
$W_{PU}(N)$	µm	Distance of N pitches of Wall and Trench at the upper surface
$W_{PB}(N)$	µm	Distance of N pitches of Wall and Trench at the bottom of trench
N	–	Number of pitches
D	µm	Depth of trench at the center of trench
θ	Deg	Sidewall angle
S_x	µm	Horizontal distance of scallop
R_{Sm}	µm	Mean vertical distance of scallop

4.3 Description

Trench structures shall be dimensioned using Figure 2 or Figure 3 in accordance with 4.1 and 4.2. See ISO 129-1[1][1] for indicating dimensions.

5 Description of needle structures in a micrometer scale

5.1 General

This standard specifies the method of indicating the geometry of needle structures in a micrometer scale. Figure 4 shows an external view of a typical needle structure. The needle structures defined in this standard are projecting structures with a pointed tip formed of three or four faces, formed on a planar substrate with the plane of symmetry in the vertical plane. The hatching plane in the figure is the plane of symmetry. The bottom face of the needle structure corresponds to the surface of the planar substrate.

See Clause 6 and Annex A for the method of measuring the geometry of needle structures.

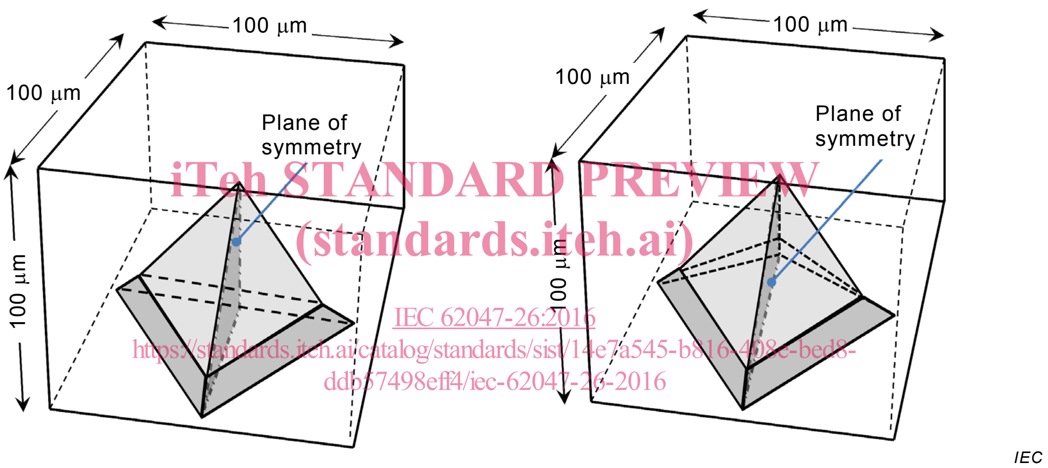


Figure 4 – Schematic of typical needle structures formed of three and four faces

5.2 Symbols and designations

Figure 5 is a three-view drawing of a typical needle structure. Table 2 lists the symbols, designations and units used for indicating the geometrical dimensions of the needle structures.

The front position of the needle structures is defined as the position where the structure shows bilateral symmetry with the plane of symmetry in the center and where the bottom face of the structure corresponds to the horizontal plane. The front position of needle structures with tips formed of three faces is the location where the two faces are in front with the plane of symmetry in the center. The front position of needle structures with tips formed of four faces is the location where the two faces with the largest area are in front with the plane of symmetry in the center.

The geometric dimensions of the needle structures specified in this standard are height of needle, H, widths at the bottom face of the needle structure, W_1 and W_2, and distance, D_1, that is the dimension shown in the top view or side view in Figure 5.

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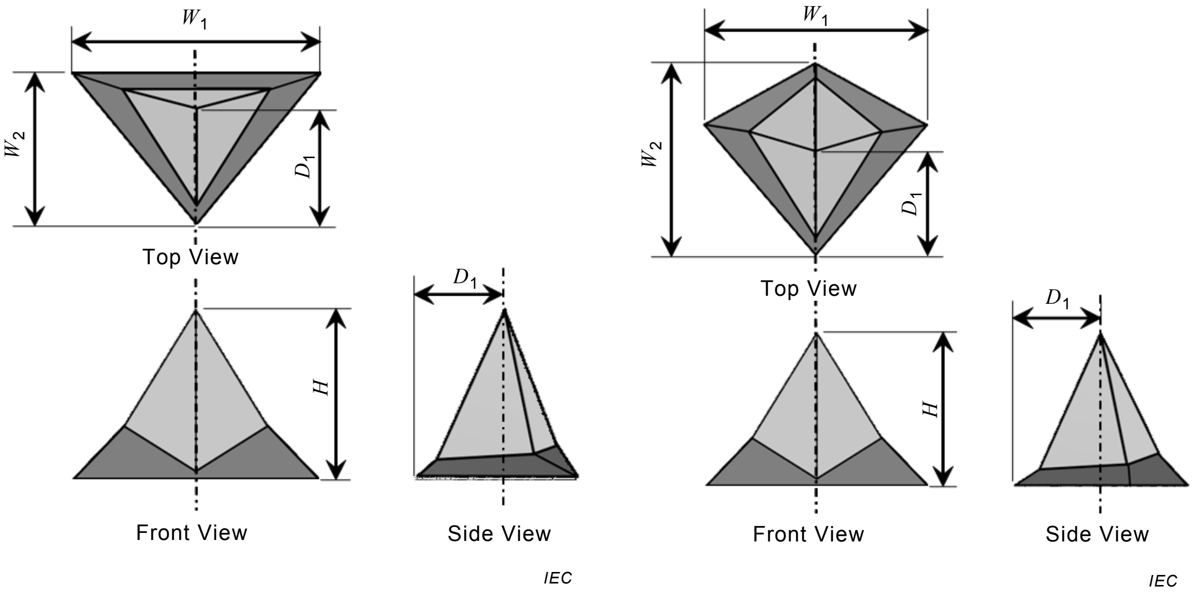
1 Numbers in square brackets refer to the Bibliography.



a) Typical needle structure with three faces **b) Typical needle structure with four faces**

Figure 5 – Front, side and top views of typical needle structures

Table 2 – Symbols and designations of needle structure in a micrometer scale

Symbol	Unit	Designation
W_1	µm	Horizontal width of needle structure at top view
W_2	µm	Vertical width of needle structure at top view
D_1	µm	Distance between tip and front point of needle structure
H	µm	Height of needle structure

5.3 Description

Needle structures shall be dimensioned using Figure 5 in accordance with 5.1 and 5.2. See ISO 129-1[1] for indicating dimensions.

6 Measurement method

See Annex A for examples of measurement for indicating the geometry of trench and needle structures. The measurement conditions required for all measurements are described as follows.

a) Record the temperature, humidity and necessary measurement conditions for each measurement.

b) Perform measurement within the dimensional scale guaranteed in the instrument used for each measurement.

c) Use instruments calibrated before each measurement.

d) For calibration of the instruments, consult the equipment supplier if necessary.

e) Maintain the levelness and perpendicularity of the sample when set in the instrument within the range guaranteed in the instrument.

f) Specify the method of straight line approximation and curve approximation required for indicating the geometry of trench structures.

g) The measurement results should be recorded in accordance with Clause B.2.

Annex A
(informative)

Examples of measurement for trench and needle structures in a micrometer scale

A.1 General

Annex A describes examples of measurement for the geometry of trench and needle structures in a micrometer scale. Clauses A.2 to A.6 summarize the principles of the measurement, the methods of the sample preparation, and the procedures of measurement in respective geometry of structures, providing one or more specific examples for measuring the geometry of trench and needle structures.

A.2 Measurement for depth of trench

A.2.1 Field emission type scanning electron microscopy

A.2.1.1 Principle of measurement

A field emission type scanning electron microscope (FE-SEM) is a device that illuminates the sample with an electron beam to produce an image of its surface features. The electron beam source is a silicon or tungsten tip which can emit electrons by applying an electric field to the tip. When the FE-SEM illuminates the sample with the electron beam, secondary electrons are also emitted from the surface of the sample. During scanning a highly focused electron beam over the surface of the sample, the secondary electrons are detected. Converting the emissions of secondary electrons into a brightness signal produces an electron micrograph.

A.2.1.2 Preparation of sample

For measuring the depth of a trench with FE-SEM, it is necessary to observe and measure the cross section of the sample directly. In order to show the cross section of the sample clearly as shown in Table 1 of 4.2, the sample should be bisected.

A.2.1.3 Procedure of measurement

The depth of the trench is the shortest distance from the horizontal datum line at the middle of the trench to the bottom surface of the trench, as described in 4.2. Perform measurement according to the procedures specified by the equipment supplier. The following points should be observed.

a) Place the sample in the SEM sample chamber so that the orientation of the FE-SEM electron beam corresponds to the normal vector of the sample cross section. The levelness of the sample should be maintained within the range guaranteed in the equipment.

b) Set the magnification so that the whole trench fits inside the SEM image.

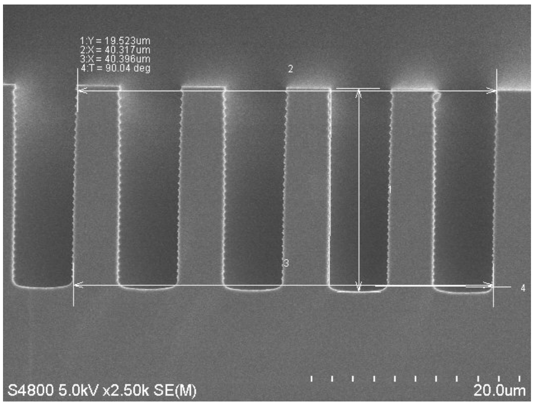
c) Adjust the focus, the contrast and so on according to the procedures specified by the equipment supplier.

d) Measure the relevant dimensions using the length measuring function provided by the equipment supplier.

e) Measure a single location the recommended number of times (see Clause B.2), and use the average of the measurement results as the measured value. See Annex B for the repeatability of measurements.

A.2.1.4 Measureable range

Measurement is applicable to trench structures within the dimensional range indicated in 4.1. Figure A.1 and Table A.1 show an example of measurement of trench depth with 2 500 times magnification using FE-SEM.



IEC

Figure A.1 – FE-SEM image of trench structure with 5 μm-wide wall and 5 μm-wide trench

Table A.1 – Example of measured data of trench depth

No.	1	2	3	4	5	6	7	8	9	10
Trench depth, D [μm]	19,6	19,5	19,6	19,6	19,5	19,6	19,5	19,5	19,5	19,6

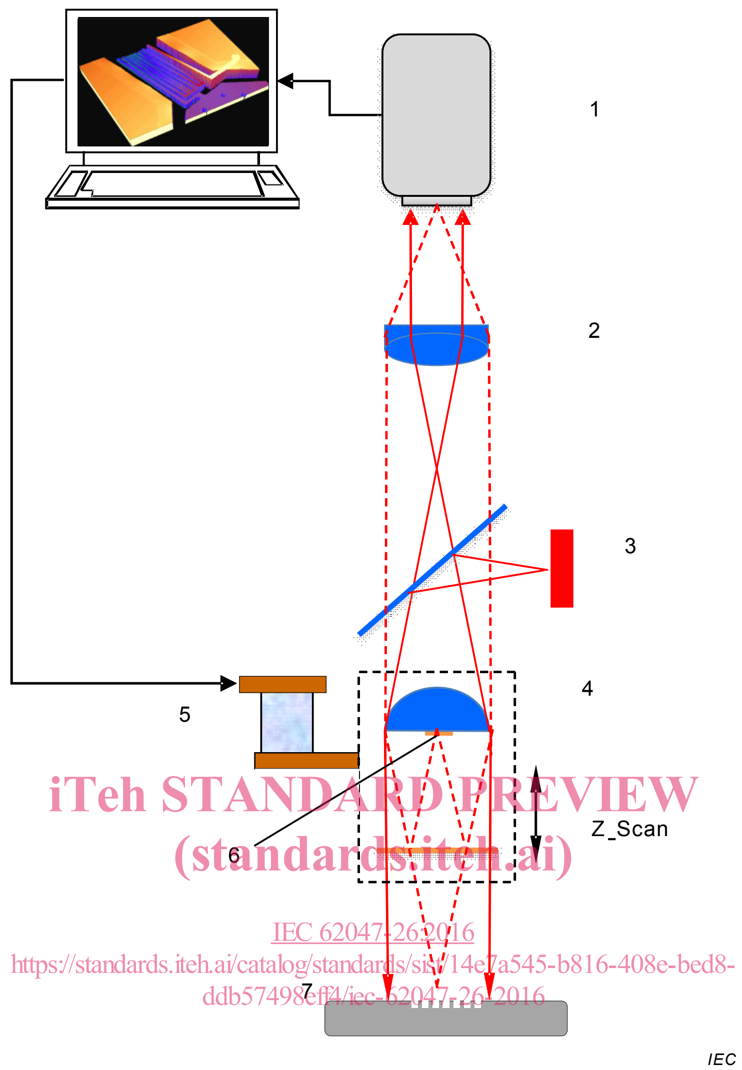
A.2.2 Coherence scanning interferometer (CSI)

A.2.2.1 Principle of measurement

A Coherence Scanning Interferometer (CSI) is a system for measuring surface profile by scanning the surface of a sample vertically with an objective lens comprising an equal-light-path interferometer.

Figure A.2a) shows the basic configuration of a CSI microscope. The sample has irregularities in the height, h, of the surface overall. The CSI microscope uses an actuator to move the interferometer objective lens smoothly and continuously in a scanning motion in the Z-scan direction shown in the figure. During scanning the sample surface, a computer records the interference brightness signal of each CCD pixel of each frame in sequence.

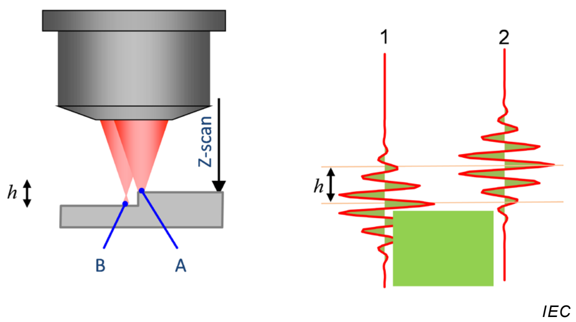
Figure A.2b) shows the two interference strength signals acquired from the vertical difference in height, h, in the surface of the sample (points A and B in the figure). The surface height of the object is determined by comparing the interference strength signal of the CCD pixels corresponding to both points. Specifically, the scanning position (the equal-light-path position) corresponding to the interference signal with the greatest contrast is found by processing each pixel in the field of view.



Key

1	CCD Camera	5	Actuator for Z-scan
2	Image lens	6	Reference mirror
3	White light source	7	Object
4	Interference objective		

a) Basic features of CSI microscope



Key

1 Intensity signal at camera pixel “B”

2 Intensity signal at camera pixel “A”

b) Intensity signal as captured by two camera pixel “A” and “B”

Figure A.2 – Schematic of CSI microscope comprising an equal-light-path interferometer