TECHNICAL SPECIFICATION

ISO/TS 24597

First edition
2011-06-15

Microbeam analysis — Scanning electron microscopy — Methods of evaluating image sharpness

Analyse par microfaisceaux — Microscopie électronique à balayage — Méthodes d'évaluation de la netteté d'image

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

Reference number
ISO/TS 24597:2011(E)

© ISO 2011

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

COPYRIGHT PROTECTED DOCUMENT

© ISO 2011

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

© ISO 2011 – All rights reserved

Contents

Page

Foreword iv

Introduction v

1 Scope 1

2 Normative references 1

3 Terms and definitions 1

4 Steps for acquisition of an SEM image 2
4.1 General 2
4.2 Specimen 2
4.3 Specimen tilt 3
4.4 Selection of the field of view 3
4.5 Selection of the pixel size 3
4.6 Brightness and contrast of the image 4
4.7 Contrast-to-noise ratio of the image 5
4.8 Focus and astigmatism of the image 7
4.9 Interference from external factors 7
4.10 Erroneous contrast 7
4.11 SEM image data file 7

5 Acquisition of an SEM image and selection of an area within the image 7

6 Evaluation methods 8
6.1 General 8
6.2 Contrast-to-noise ratio 9
6.3 Fourier transform (FT) method 9
6.4 Contrast-to-gradient (CG) method 12
6.5 Derivative (DR) method 16

7 Test report 18
7.1 General 18
7.2 Contents of test report 18

Annex A (normative) **Details of contrast-to-noise ratio (CNR)** 19

Annex B (normative) **Details of the Fourier transform (FT) method** 24

Annex C (normative) **Details of the contrast-to-gradient (CG) method** 40

Annex D (normative) **Details of the derivative (DR) method** 51

Annex E (informative) **Background to evaluation of image sharpness** 72

Annex F (informative) **Characteristics and suitability of the various evaluation methods** 77

Annex G (informative) **Method of preparing test specimens for evaluating image sharpness** 81

Annex H (informative) **Example of test report** 83

Bibliography 86

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70b82872a38/iso-ts-24597-2011

© ISO 2011 – All rights reserved

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/1af24f02-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

ISO/TS 24597 was prepared by Technical Committee ISO/TC 202, *Microbeam analysis*, Subcommittee SC 4, *Scanning electron microscopy (SEM)*.

© ISO 2011 – All rights reserved

Introduction

The International Organization for Standardization (ISO) draws attention to the fact it is claimed that compliance with this document may involve the use of patents concerning the evaluation method using the contrast-to-gradient (CG) method given in 6.4.

ISO takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured ISO that he/she is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Information may be obtained from:

Patent holder: Hitachi, Ltd.

Address: Marunouchi Center Bldg., 6-1, Marunouchi 1-chome, Chiyoda-ku, Tokyo, 100-8220, Japan.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

© ISO 2011 – All rights reserved

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

Microbeam analysis — Scanning electron microscopy — Methods of evaluating image sharpness

1 Scope

This Technical Specification specifies methods of evaluating the sharpness of digitized images generated by a scanning electron microscope (SEM) by means of a Fourier transform (FT) method, a contrast-to-gradient (CG) method and a derivative (DR) method.

2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 16700:2004, *Microbeam analysis — Scanning electron microscopy — Guidelines for calibrating image magnification*

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/b124f492-8953-479b-9eb6-70bc82872a38/iso-ts-24597-2011

ISO 22493, *Microbeam analysis — Scanning electron microscopy — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16700 and ISO 22493 and the following apply.

3.1
pixel
smallest non-divisible image-forming unit on a digitized SEM image

3.2
pixel size
specimen length, in nanometres, per pixel in an SEM image

NOTE The horizontal and vertical pixel sizes should be same.

3.3
binary SEM image
converted SEM image in which there are only two brightness levels

3.4
convoluted image
image obtained by convolution of a binary SEM image with a two-dimensional Gaussian profile

3.5
sharpness factor
twofold standard deviation (2σ) of the Gaussian profile used to make a convoluted image

© ISO 2011 – All rights reserved

3.6
image sharpness
sharpness factor divided by the square root of 2 (i.e. $2\sigma/\sqrt{2}$), the sharpness factor of an SEM image being considered the same as that of a convoluted image produced with a Gaussian profile of standard deviation σ

3.7
contrast-to-noise ratio
CNR
ratio of $I_A - I_B$ to σ_n, where I_A and I_B are the image intensities for the object and the background and σ_n is the standard deviation of the image noise

3.8
Fourier transform method
FT method
method of evaluating image sharpness by comparing Fourier transform profiles of an SEM image with those of convoluted images

3.9
contrast-to-gradient method
CG method
method of evaluating image sharpness using weighted harmonic mean gradients of the two-dimensional brightness distribution map of an SEM image

3.10
derivative method
DR method
method of evaluating image sharpness by fitting error function profiles to gradient directional-edge profiles of particles in an SEM image

iTeh STANDARD PREVIEW
(standards.iteh.ai)

3.11
field of view
area of a specimen that corresponds to the whole SEM image

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

4 Steps for acquisition of an SEM image

4.1 General

For SEM image acquisition, it is important to first adjust the microscope conditions (for example, see Annex B in ISO 16700:2004). Image sharpness is dependent upon (i) the specimen itself, (ii) the structural smoothness of the foreground and the background of the image, (iii) the brightness and contrast and (iv) the contrast-to-noise ratio (CNR). Therefore, follow the procedures described in 4.2 to 4.10 corresponding to the above factors for evaluation of image sharpness by all the three methods described herein. Particular attention must be paid to the adjustment of the electron probe current and the focussing conditions in order to obtain the optimum requirements for brightness and contrast (see 4.6) and contrast-to-noise ratio (see 4.7).

4.2 Specimen

At the date of publication of this document, there was no designated certified reference material (CRM). Acceptable results can, however, be obtained using a specimen prepared by the method described in Annex G. Select a specimen with a smooth and flat surface. For evaluations of the image sharpness, choose a part of the specimen which contains circular particles deposited on the substrate. Obtain the desired images at the chosen magnification in accordance with 4.4.

NOTE Material which is sensitive to the electron dose is not suitable for use as a specimen for the evaluation of image sharpness.

© ISO 2011 – All rights reserved

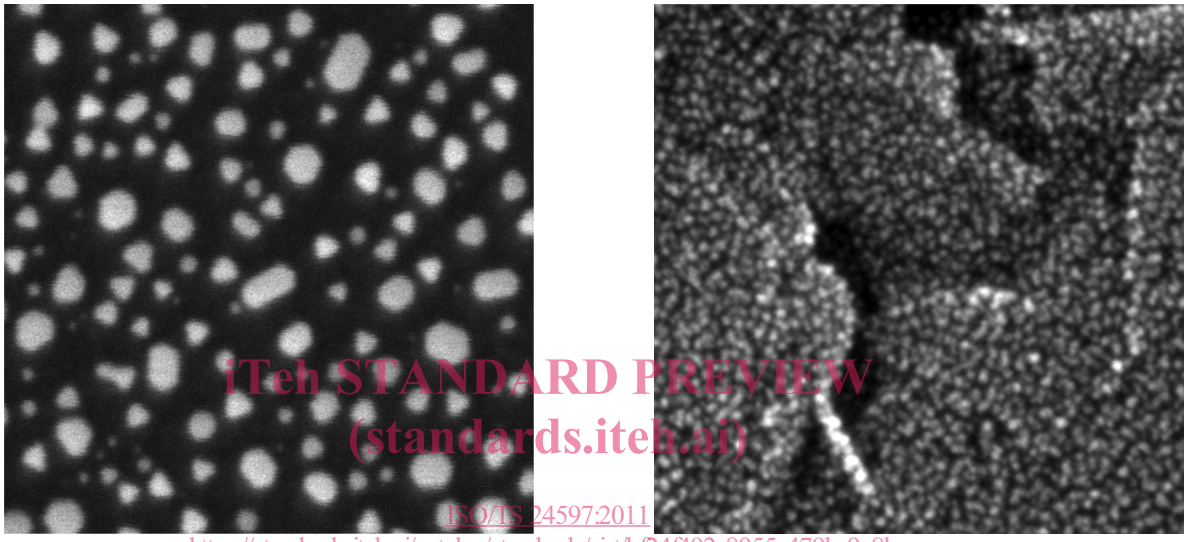
4.3 Specimen tilt

Set the specimen tilt angle at 0° (non-tilting condition).

NOTE Errors within ±3° in the tilt angle of the specimen will not affect the evaluation of the image sharpness.

4.4 Selection of the field of view

Select the field of view so that it contains a flat and smooth surface because image sharpness varies with the evenness (or rather unevenness) of the surface. Figures 1 a) and b) show acceptable and unacceptable fields of view, respectively. Choose particles extending over several tens of pixels [see Figure 1 a)].



iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

a) Acceptable image b) Unacceptable image

Figure 1 — SEM images with a) acceptable and b) unacceptable structured foreground images

4.5 Selection of the pixel size

4.5.1 General

Before evaluating the image sharpness, it is necessary to calibrate the image magnification and/or the scale marker in accordance with ISO 16700.

4.5.2 Determination of the pixel size from a field of view

The pixel size L_p (in nm) is determined from the following equation:

$$L_p = \frac{L_{FOV}}{N_p}$$

where

L_{FOV} is the horizontal width of the field of view on an SEM image, in nm;

N_p is the number of pixels covering the horizontal width of the field of view.

© ISO 2011 – All rights reserved

4.5.3 Determination of the pixel size from a scale marker

The pixel size L_p (in nm) is calculated by using a scale marker as follows:

$$L_p = \frac{L_{scale}}{N_{scale}}$$

where

L_{scale} is the “indicator” value (e.g. the nominal value, in nm) of the scale marker;

N_{scale} is the number of pixels covering the length of the scale marker.

4.5.4 Conversion of the pixel size

The image sharpness as derived by the methods described herein (R_{PX}) is in pixels. Converted to nanometres, the image sharpness R_L is then given by the expression:

$$R_L = L_p \times R_{PX}$$

where L_p is the pixel size.

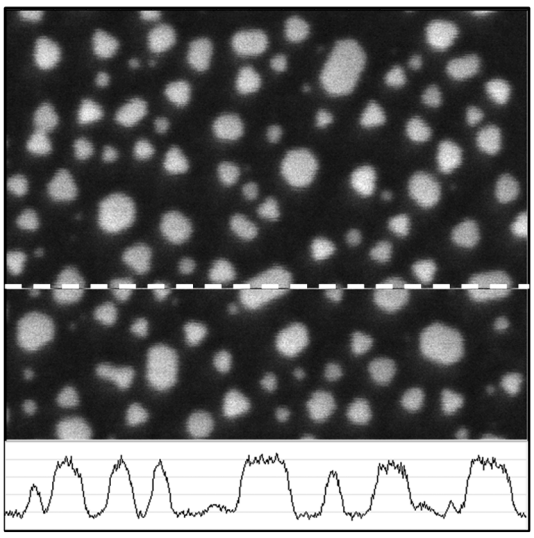
Set the pixel size to about 40 % of the expected value of the image sharpness. For example, set the pixel size to 0,8 nm when the image sharpness is expected to be 2 nm.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

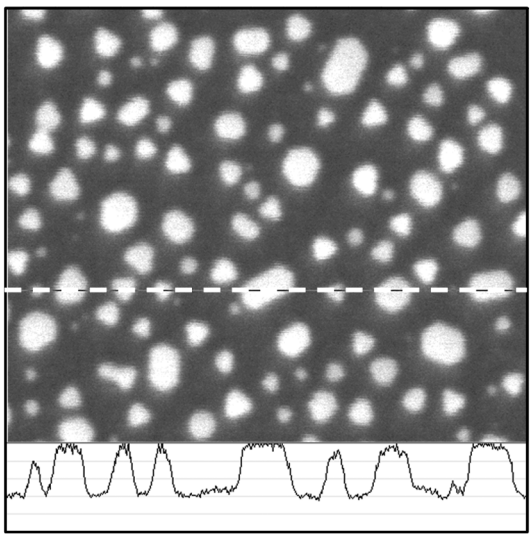
4.6 Brightness and contrast of the image

The signal intensity of the image should be widely distributed. Figures 2 a), b), c) and d) show examples of images with acceptable and unacceptable brightness and contrast. Line profiles corresponding to the dotted lines at the same vertical position in each image are shown for visual guidance.

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011



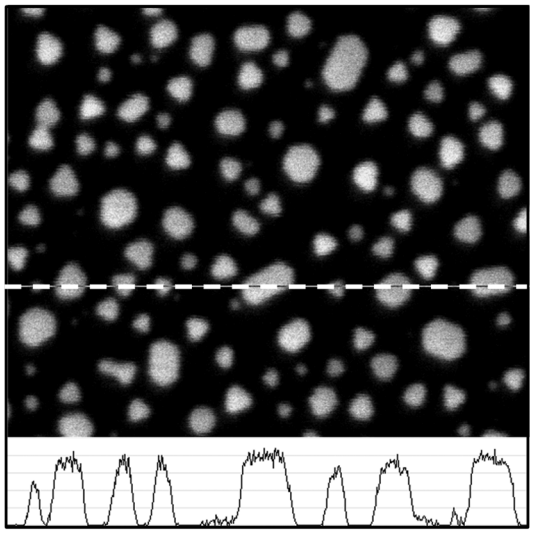
a) Acceptable image



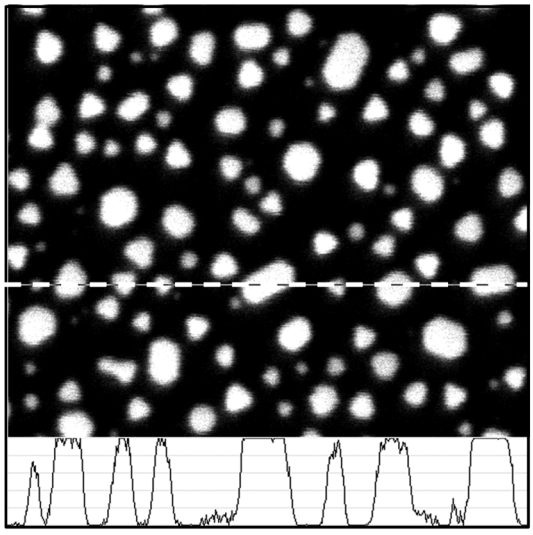
b) Unacceptable (over-saturated) image

Figure 2 (*continued*)

© ISO 2011 – All rights reserved



c) Unacceptable (under-saturated) image



d) Unacceptable (over-saturated) image

Figure 2 — SEM images with acceptable and unacceptable brightness and contrast

4.7 Contrast-to-noise ratio of the image

iTeh STANDARD PREVIEW
(standards.iteh.ai)

The contrast-to-noise ratio (CNR) of the image shall be 10 or larger. Here, the CNR is defined as the ratio of the image contrast C_{image} to the standard deviation σ_n of the image noise (see Figure 3).

$$\text{CNR} = C_{\text{image}}/\sigma_n$$

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc85f52e38/iso-ts-24597-2011

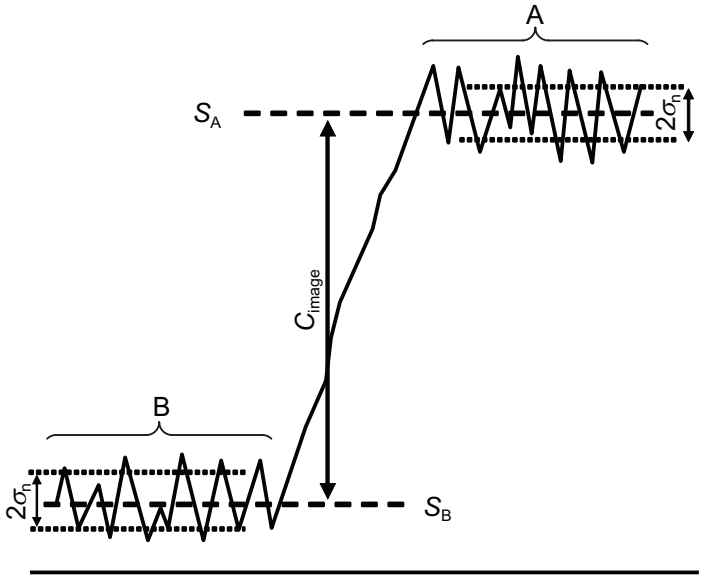
A procedure for the determination of the CNR ratio is given in Annex A.

Figure 4 shows the simulated appearance of images with CNRs of 5, 10 and 50.

Figure 5 shows examples of SEM images with different CNRs of about 4 and 30.

NOTE In order to obtain SEM images with a good CNR, it is necessary to adjust the probe current and/or the image acquisition time. One should be aware of the fact that variations in the above parameters will affect the results of the image sharpness evaluation.

© ISO 2011 – All rights reserved



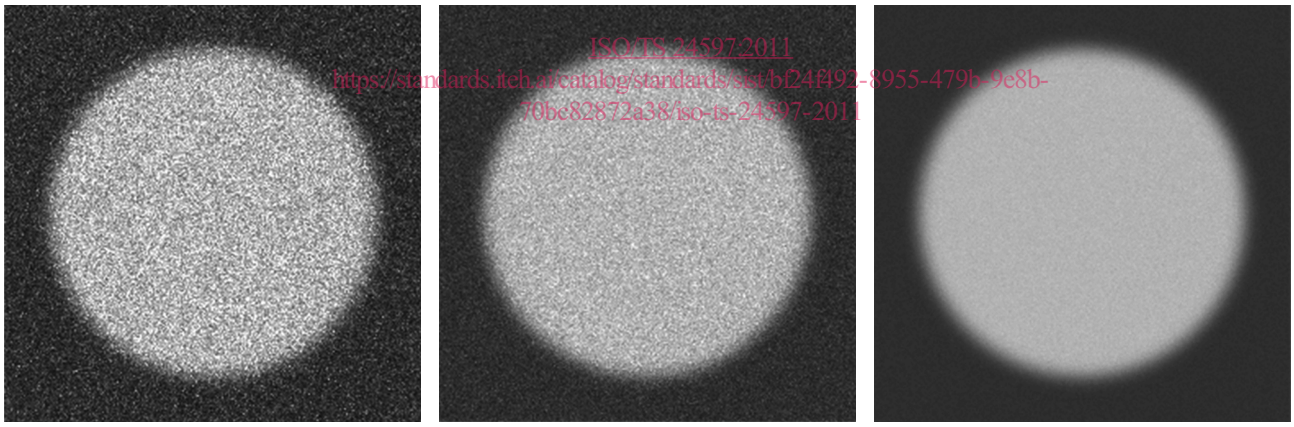
Key

A region A

B region B

Figure 3 — Intensity profile of an image

iTeh STANDARD PREVIEW
(standards.iteh.ai)

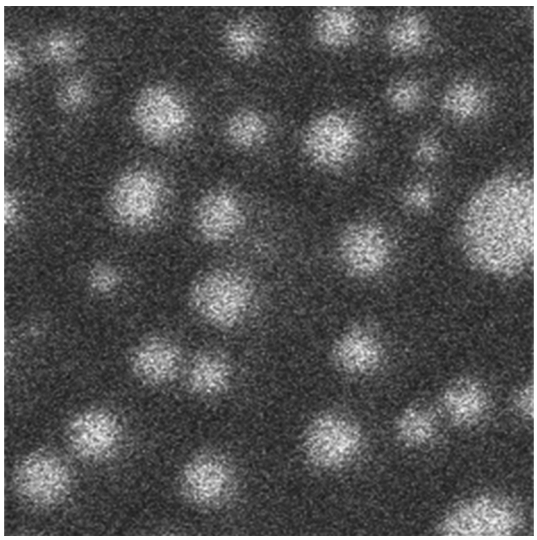


ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70be82872a38/iso-ts-24597-2011

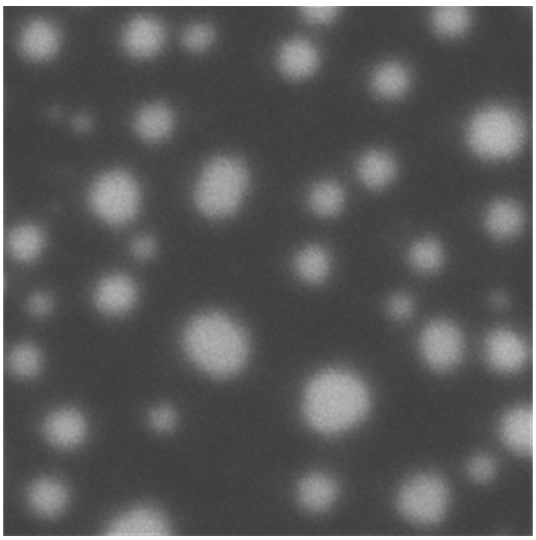
a) CNR = 5 **b) CNR = 10** **c) CNR = 50**

Figure 4 — Simulated images with different contrast-to-noise ratios

© ISO 2011 – All rights reserved



a) Low contrast-to-noise ratio (CNR ≈ 4)



b) High contrast-to-noise ratio (CNR ≈ 30)

Figure 5 — SEM images with different contrast-to-noise ratios

4.8 Focus and astigmatism of the image

iTeh STANDARD PREVIEW

Focus the electron beam as well as possible. Use an image that is as free of astigmatism as possible.

(standards.iteh.ai)

4.9 Interference from external factors

External factors such as mechanical vibration, distortion by magnetic fields and those listed in Annex B of ISO 16700:2004 affect the image sharpness. Ensure, as far as possible, that the images used are not affected by these factors.

ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/2d4f0c2e-5f2d-4f0c-9e4b-70bc82872a38/iso-ts-24597-2011

4.10 Erroneous contrast

Make sure that the images do not contain erroneous contrast (e.g. contrast due to charging of the specimen).

4.11 SEM image data file

The image data, which is directly saved from an SEM, shall be in digital format, with the grey scale at least 8 bits deep. The data file of the image shall be in an uncompressed graphics-file format, e.g. uncompressed bitmap or uncompressed TIF.

Do not use the data obtained from a printed SEM image.

5 Acquisition of an SEM image and selection of an area within the image

The procedure described in this clause is common to all those used in this Technical Specification (see Clause 6).

a) Use a specimen prepared by the procedure described in 4.2. Acquire an image, paying attention to the instructions given in 4.3 to 4.10.

b) Select a square area in the SEM image (hereafter referred to as the image) comprising at least 256×256 pixels. The area shall not have any superimposed extraneous data (e.g. magnification display, scale marker, characters, arrows, etc.).

   Choose an area containing images of preferably non-overlapping particles.

c) Store the selected SEM image in a data file in an uncompressed graphics-file format specified in 4.11.

© ISO 2011 – All rights reserved

6 Evaluation methods

6.1 General

The evaluation methods described in 6.3 to 6.5 are based on the assumption that the electron beam has a Gaussian profile. Hence the results obtained by these methods do not represent the actual beam size (see Clause E.4). Figure 6 shows a general flow chart for the evaluation of an SEM image, including the common procedure for evaluation of the CNR given in Clause 5.

Basic procedures for obtaining the image sharpness are as follows:

a) Select an SEM image by following Clause 5.

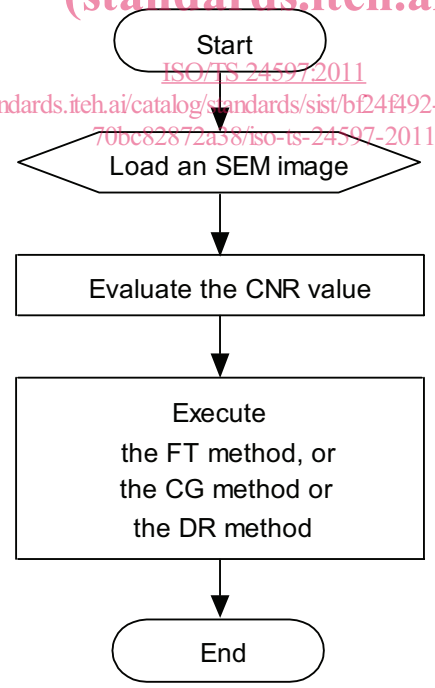
b) Determine the CNR for the selected SEM image (see 6.2) and ensure that it is larger than or equal to 10 before proceeding further.

c) Calculate the sharpness factor 2σ for the selected SEM image in the frequency space or the real space (depending on method used). Here, the sharpness of an SEM image is determined from an equivalent image produced by convolution of a binary SEM image with a two-dimensional Gaussian profile with a sharpness factor 2σ (i.e. a twofold standard deviation).

NOTE The calculation procedure depends on the method used.

d) The image sharpness is defined as $k \times 2\sigma$, where $k = 1/\sqrt{2}$.

iTeh STANDARD PREVIEW
(standards.iteh.ai)



ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/bf24f492-8955-479b-9e8b-70bc82872a38/iso-ts-24597-2011

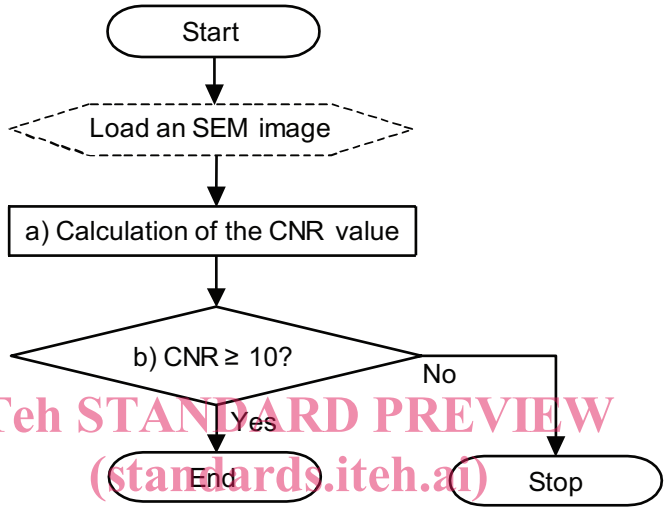
Figure 6 — General flow chart for the evaluation of an SEM image

© ISO 2011 – All rights reserved

6.2 Contrast-to-noise ratio

The basic concept of the contrast-to-noise ratio (see 4.7) was developed in the medical imaging field. The CNR for the selected SEM image of interest shall be evaluated. Only images with CNR = 10 or larger can be passed on to the next step for evaluating image sharpness. Figure 7 shows a brief flow chart for the CNR evaluation following routines a) and b). Details of the routines are described in Annex A.

If the value of CNR is < 10, discard the SEM image. Acquire a new SEM image with lower noise and carry out the evaluation again.



iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TS 24597:2011
https://standards.iteh.ai/catalog/standards/sist/...
70bc82872a38/iso-ts-24597-2011

Figure 7 — Flow chart for the evaluation of the CNR

6.3 Fourier transform (FT) method

For evaluating image sharpness, the Fourier transform (FT) method is used with the spatial frequency components given by the FT of an SEM image. The spatial frequency components of the SEM image are compared with those of the images obtained by the convolution of the binarized SEM image with Gaussian profiles with various sharpness factors 2σ (see Figures 8 and 9). Details of procedures for the FT method are given in Annex B.

NOTE The signal intensity of an image I_m is expressed as $I_m(i, j)$, and the coordinates i and j are chosen as 0, 1, …, $L - 1$ for an image with x- and y-size L (= 256, 512, …). However, the coordinates i and j are treated as integers ranging from $-L/2$ to $(L/2) - 1$ for the FT pattern.

© ISO 2011 – All rights reserved