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Edition 1.0 2016-07

TECHNICAL SPECIFICATION

colour inside

Test methods for electrical materials, printed boards and other interconnection structures and assemblies –
Part 3-301: Test methods for interconnection structures (printed boards) – Appearance inspection method for plated surfaces on PWB

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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

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 3-301: Test methods for interconnection structures (printed boards) – Appearance inspection method for plated surfaces on PWB

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61189-3-301, which is a technical specification, has been prepared by IEC technical committee 91: Electronics assembly technology.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
91/1348/DTS	91/1376/RVC

Full information on the voting for the approval of this technical specification 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 61189 series, published under the general title *Test methods for electrical materials, printed boards and other interconnection structures and assemblies*, 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 3-301: Test methods for interconnection structures (printed boards) – Appearance inspection method for plated surfaces on PWB

1 Scope

This part of IEC 61189 outlines a way to determine the appearance non-uniformity of both the lustre and colour on plated metal surfaces in printed wiring boards (PWBs). The method is applicable to gold, nickel and copper plating in PWBs.

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
lustre non-uniformity
abnormal roughness distribution in plated surfaces leading to irregular brightness of reflected light

3.2
colour non-uniformity
irregular reflection spectrum

Note 1 to entry: Colour non-uniformity is caused by other influences than roughness change, such as abnormal components, adhesion of foreign matter and oxidation in plated surfaces.

4 Test specimens

4.1 Specimen dimensions and forms should be in accordance with the test system.

4.2 Specimens of non-defective and of defective products, of several tens to one hundred, at least of ten, are required as teacher data for each series of evaluation.

5 Equipment / apparatus

5.1 Evaluation of lustre non-uniformity

For the evaluation of the lustre non-uniformity, a test system capable of measuring the surface roughness distribution should be used. As for an optical method, CCD (chargecoupled device), or CMOS (complementary metal oxide semiconductor) camera systems, or as for a mechanical method, stylus type tester shall be used, respectively.

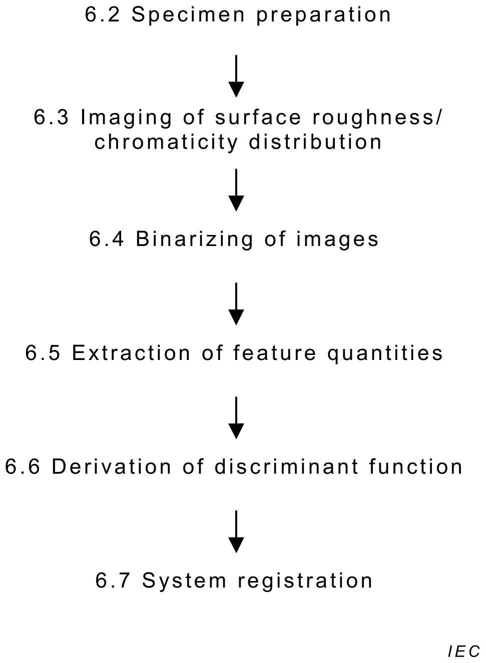
5.2 Evaluation of colour non-uniformity

For the evaluation of the colour non-uniformity, an optical system capable of measuring the chromaticity distribution shall be used.

6 Procedure

6.1 Outline of the method

The method is outlined by the flow chart in Figure 1.



The numbers indicate the subclause references.

Figure 1 – Flow chart of the test procedure

In this method, the procedures of the evaluation of lustre non-uniformity and colour non-uniformity are basically the same.

6.2 Specimen preparation

Requirements for specimens are specified in Clause 4.

6.3 Imaging of surface roughness/chromaticity distribution

Acquire the images of surface roughness for the lustre non-uniformity, and/or of chromaticity distribution for the colour non-uniformity, by the apparatus / equipment mentioned in Clause 5.

6.4 Binarization of images

Obtain the binary images by the threshold processing. The region giving values significantly deviating from the average value of the whole image concerned is counted to be 1 (white pixels) as abnormal, and the others to be 0 (black pixels) as normal.

The threshold setting should be agreed upon between the parties.

6.5 Extraction of feature quantities

Extract the feature quantities of abnormal regions from the binarized images by image analysis of the size, area, shape, and distribution, etc. of the irregularities.

For example, the diagonal length of the minimum rectangles bounding the clusters of abnormal regions, and change in the number of pixels by the binary image contraction of repetition can be used as feature quantities.

The type and number of feature quantities to be used should be agreed upon between the parties.

6.6 Derivation of discriminant function

Discriminant analysis shall be performed using the feature quantities extracted from specimens of non-defective and defective products as indicated in 6.5 as the teacher data to split into two groups.

The linear discriminant function is expressed by Equation (1):

$$Z = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \cdots + a_iX_i + \cdots \quad (1)$$

where

- Z is the discriminant score;
- a_0 is a constant;
- i (subscript) indicates the dimensions of the discriminant function;
- a_i is the discriminant coefficient as weighting factor for the separation of test specimens of teacher data into the two groups, non-defective and defective;
- X_i is the frequency of feature quantities taken into consideration.

Equation (1) is defined to distinguish the group of non-defective specimens from the group of defective specimens by the value Z, which is respectively set to be positive for non-defective and negative for defective specimens by adjusting a_i, and a_0.

If necessary, the type of non-linear discriminant function based on Mahalanobis' generalized distance, D^2 may also be used.

The type of the discriminant function to be used can be agreed upon between the parties.

6.7 System registration

The resulting discriminant function shall be registered to the test system to perform evaluation of unknown specimens.

For the unknown specimen, the value of Z shall be calculated using the registered function, which is defined by Equation (1) in advance in the linear discriminant analysis.

From the values of Z obtained, the quality of the unknown specimen can be estimated.

In case of a non-linear discriminant function, the values of D^2 shall be used for the estimate of unknown specimens.

7 Report

7.1 Report the specimen numbers of both non-defective and defective products used as the teacher data.

7.2 Report the apparatus / equipment information for capturing images of plated surfaces in the tested specimens.

7.3 Report the value of threshold for the binarizing images.

7.4 Report the type, stepping width, and range of the feature quantities extracted from the binarized images.

7.5 Report the discriminant function derived for evaluation of the tested specimens.

8 Additional information

8.1 An optical method based on the polarization analysis and image recognition has been proposed from AIST, Japan, and a powerful camera system that can observe both a lustre irregularity and uneven colouring at the same time has been developed.

8.2 Examples of the equipment and tested results are shown in Annex A and Annex B.

Annex A
(informative)

Example of equipment and tested result for lustre non-uniformity

A.1 Equipment for lustre non-uniformity inspection

Figure A.1 shows the test equipment prototyped for the lustre non-uniformity.

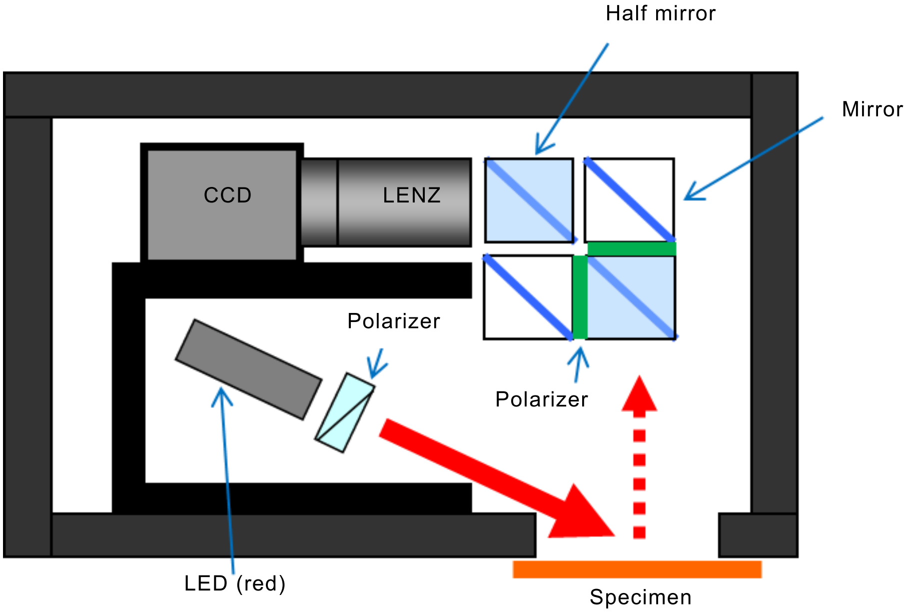


Figure A.1 – Equipment prototype

The incident light that illuminated the sample was linearly polarized and tilted at 45° to have the ratio of 1/1 for the S-/P-polarized components. The reflected light was separated by a half mirror and passed the S and P polarizers for independent imaging by the CCD camera. In order to obtain distribution images of the surface roughness, the CCD images captured were analyzed by comparing each pixel of the images of the S- and P-polarized components.

Mapping of the surface roughness according to the pixel size can be achieved using this method.

A.2 Tested result

A.2.1 Surface roughness image

Figure A.2 shows the examples of images of gold-plated pads of non-defective (see a to c) and defective products (see d to l) with various types of lustre non-uniformity in PWBs, captured by a CCD camera.

Figure A.3 shows the example of surface roughness images analyzed by the equipment of Figure A.1 for gold plating of defective specimens with lustre non-uniformity. Images of S-polarized (see a, d, g), P-polarized (see b, e, h) components, and Ψ’(see c, f, i), calculated from the ratio of S- to P-polarized components indicate the surface roughness distribution for gold-plating with lustre non-uniformity in PWBs.

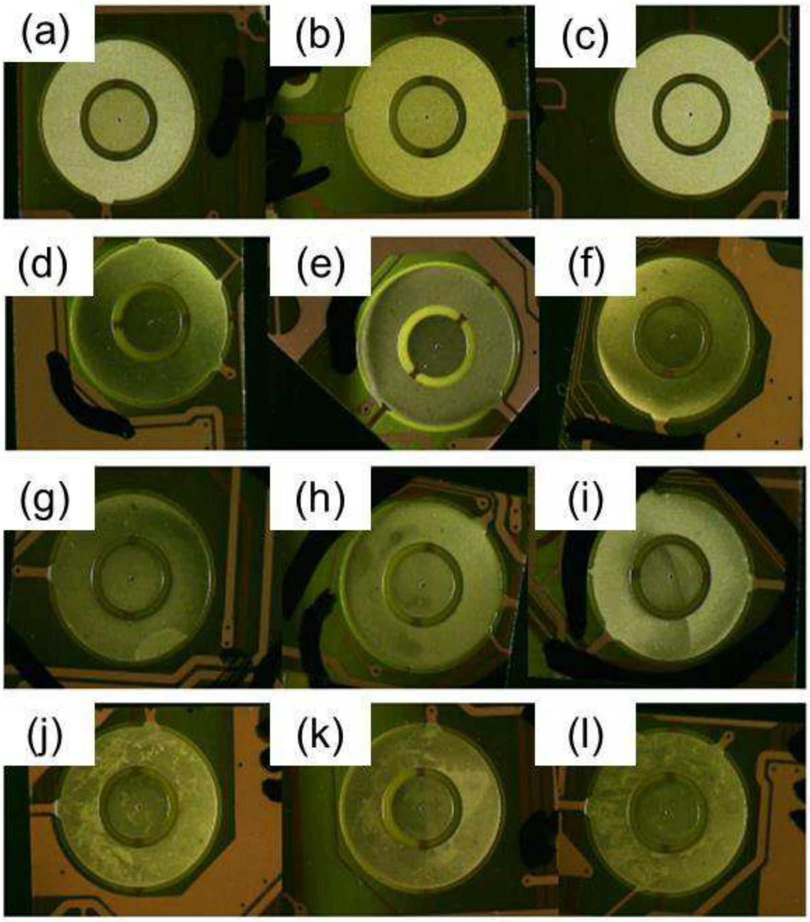


Figure A.2 – Images of gold-plating of non-defective and defective products

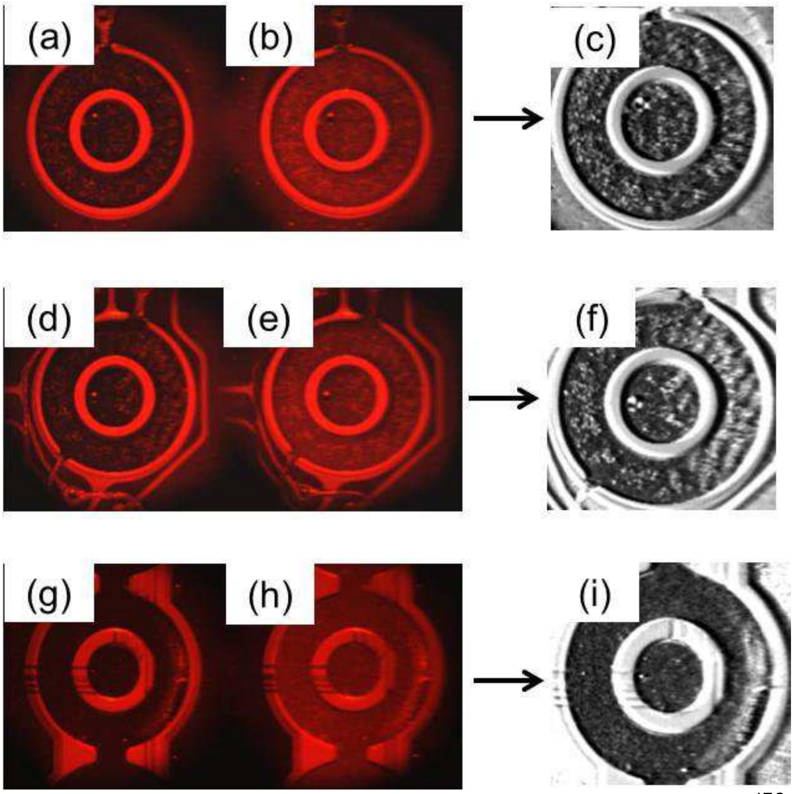


Figure A.3 – Images of S- and P-polarized components, and Ψ’ for gold-plating with lustre non-uniformity

A.2.2 Binarized image and feature extraction

Figure A.4 a) shows an example of a binarized image of abnormal portions in the series of specimens shown in Figure A.2 and Figure A.3. The threshold for binarization is set as follows: regions giving values within ±10 % of the average value are classified as normal, and those beyond this limit are counted as abnormal (white pixels).

Figure A.4 b) shows an example of extraction of feature quantities of abnormal portions using the minimum rectangles bounding the clusters of white pixels. The diagonal length of the minimum rectangles is defined as the feature quantity, expressed as L_i.

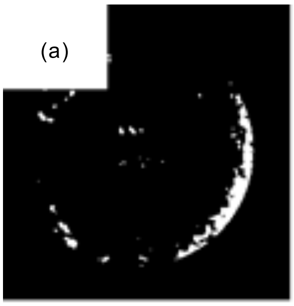


Figure A.4 a) – Binarized image

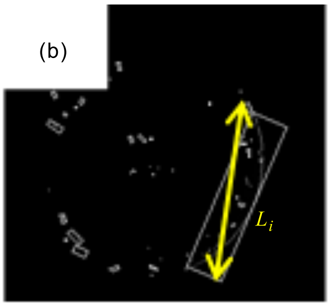


Figure A.4 b) – Feature quantity

Figure A.4 – Image examples of gold-plating with lustre non-uniformity

A.2.3 Frequency analysis of feature quantities

Figure A.5 shows an example of a frequency analysis of the feature quantities of gold-plating L_i to obtain each frequency, X_i.

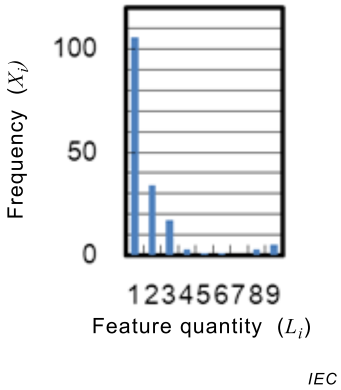


Figure A.5 – Example of frequency analysis of feature quantity

A.2.4 Final estimate

Figure A.6 shows an example of the linear discriminant analysis result using specimens of gold-plating of non-defective and defective products as the teacher data to determine the quality of the object specimens corresponding to boundary specimens.

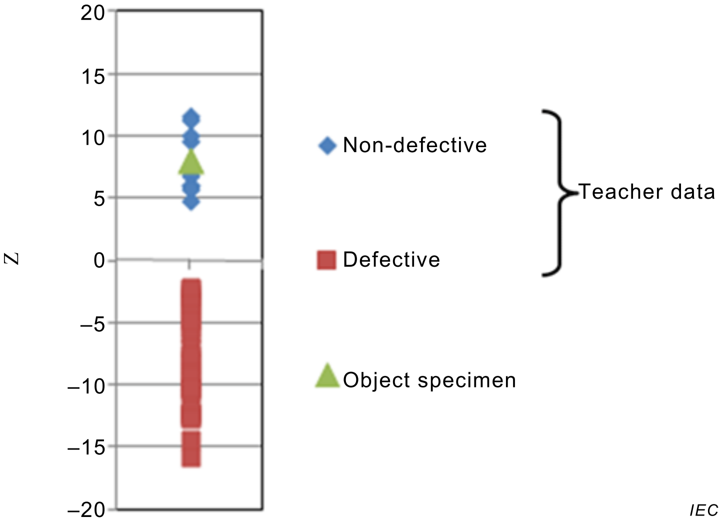


Figure A.6 – Example of the final estimate of the quality of gold-plating

As shown in Figure A.6, Z of a non-defective product takes a value above 0, in the range +5 to +12. In contrast, Z of a defective product takes a value below 0, in the range –2 to –16. Using this function, Z of an unknown (object) specimen is evaluated to be 7, and this result estimates the specimen as non-defective, and the judgment agrees with that obtained by visual inspection.

In this way, the criteria for acceptability can be provided using the discriminant function. As a result, objective determination and classification criteria can be obtained for the digitization of the lustre non-uniformity of gold plating.

Annex B
(informative)

Example of tested result for colour non-uniformity inspection

B.1 Image analysis of colour non-uniformity

Colour non-uniformity has been analyzed using the ratios of different colour signal settings such as green to red (G/R), blue to green (B/G), and red to blue (R/B) in images captured by a CCD camera for gold-plating pads in defective specimens of PWB.

Figure B.1 shows an example of a result of colour non-uniformity analysis using the ratio of G/R, which gives the clearest change (comparing to the ratios of B/G and R/B in this experiment).

The images of Figure B.1 display the following gold-plating pads (500 µm × 500 µm)

a) colour non-uniformity,

b) the magnified view,

c) and the colour distribution in G/R, with the signal intensity ratio of green to red, as a function of pixel position in a CCD camera.

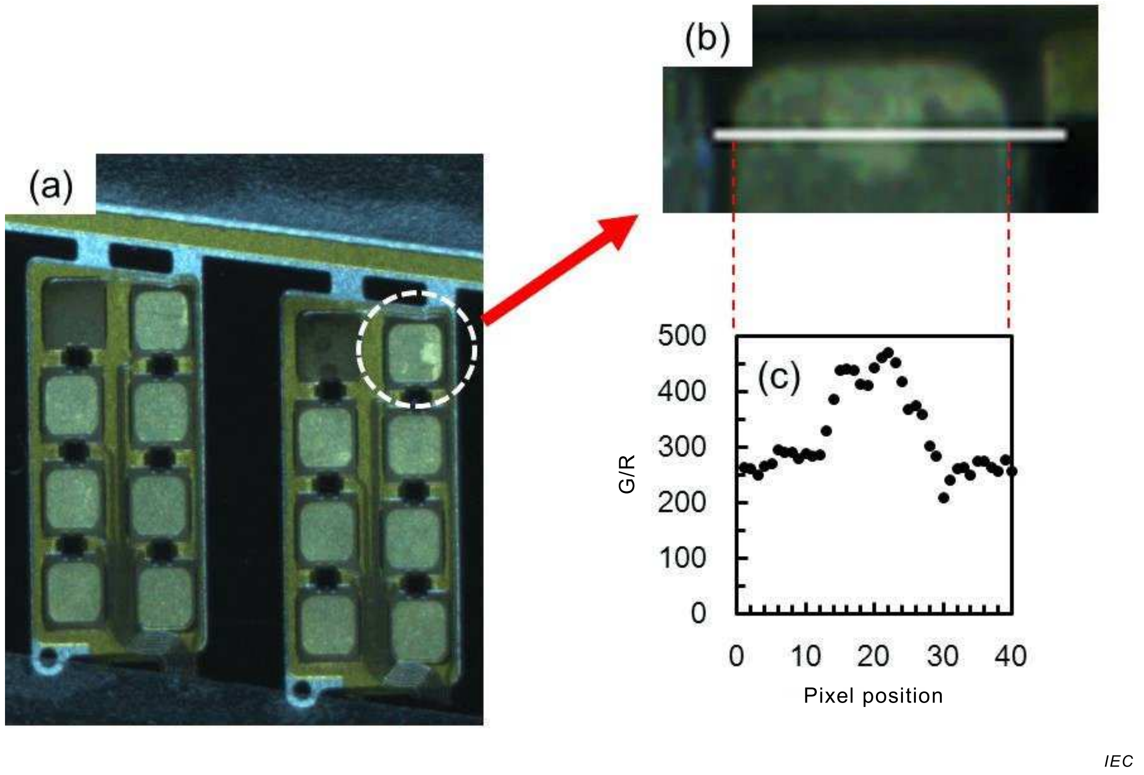


Figure B.1 – Images of gold-plating pads

Figure B.2 shows the examples of images of G/R and threshold images for the same specimen as shown in Figure B.1. In Figure B.2 b), the regions detected as colour non-uniformity are marked in red.

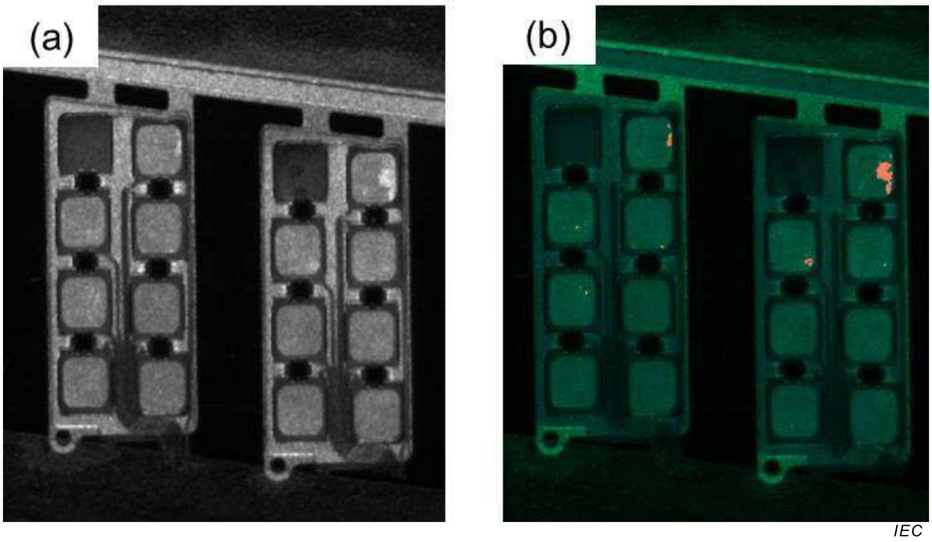


Figure B.2 a) – G/R colour distribution

Figure B.2 b) – Threshold images

Figure B.2 – Images of colour distribution

B.2 Feature extraction and discriminant analysis

Figure B.3 shows an example of frequency analysis result of the feature quantity extracted from gold-plating with colour non-uniformity as shown in Figure B.2. For the feature quantity, the number of times that the images were contracted is used to count the numbers of pixels remaining in the resulted images. This extracting method is found to be suitable comparing to the method using the length of diagonals in roughness mode irregularities shown in Figure A.4 b). The classification of the quality has been performed by visual inspection of skilled testers in advance.

Figure B.3 illustrates an example of a frequency analysis of the feature quantity of gold-plating in non-defective (No.1-84) and defective specimens (No.85-105) with colour non-uniformity. For the feature quantity, the number of times that the images were contracted is used to count the numbers of pixels remaining in the resulting images.

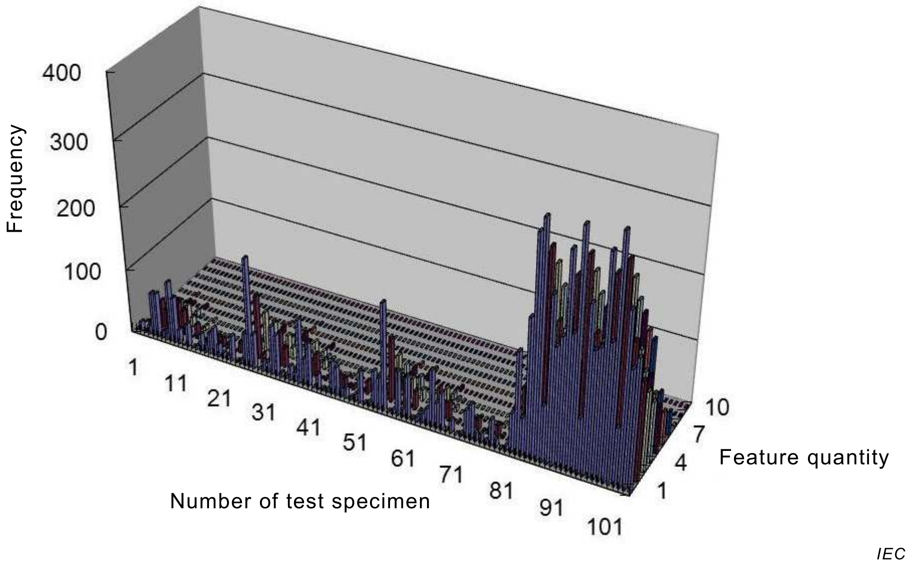


Figure B.3 – Frequency analysis example of a feature quantity

Figure B.4 shows an example of the linear discriminant analysis result for the specimens of gold-plating of non-defective (No.1-84) and defective specimens (No.85-105) with colour non-uniformity. The specimens of non-defective products give positive values of Z, while defective ones reveal negative values of Z. The specimens are the same as those shown in Figure B.3.

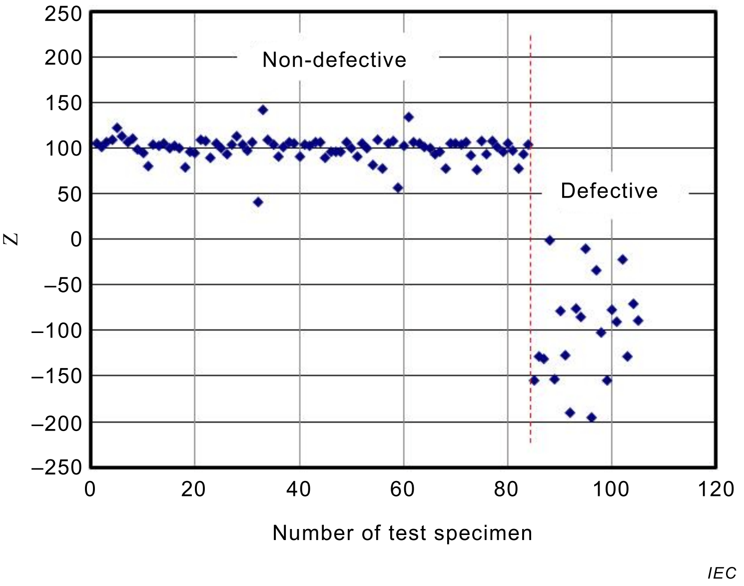


Figure B.4 – Example of the discriminant analysis result

Bibliography

[1] Kazuhiro Nonaka, Toshihiro Kamohara, Toshiaki Koga, Kazufumi Sakai, and Kousuke Miura, *Development of Compact Inspection Apparatus for the Digitization of Nonuniformity in the Luster of Gold Plating*, Proceedings of the ECWC13, 2014

[2] Brian J. DeBoo, Jose M. Sasian, and Russell A. Chipman, *Depolarization of diffusely reflecting man-made objects*, APPLIED OPTICS, 2005

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

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