IEC TR 62866

Edition 1.0 2014-05

TECHNICAL REPORT

RAPPORT TECHNIQUE

colour inside

Electrochemical migration in printed wiring boards and assemblies – Mechanisms and testing

Migration électrochimique dans les cartes a circuits imprimés et assemblages – Mécanismes et essais

IEC TR 62866:2014-05(en-fr)

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

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC TR 62866

Edition 1.0 2014-05

TECHNICAL REPORT

RAPPORT TECHNIQUE

colour inside

Electrochemical migration in printed wiring boards and assemblies – Mechanisms and testing

Migration électrochimique dans les cartes a circuits imprimés et assemblages – Mécanismes et essais

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX XD

ICS 31.180

ISBN 978-2-8322-1559-3

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

ELECTROCHEMICAL MIGRATION IN PRINTED WIRING BOARDS AND ASSEMBLIES – MECHANISMS AND TESTING

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC/TR 62866, which is a technical report, has been prepared by IEC technical committee 91: Electronics assembly technology.

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

Enquiry draft	Report on voting
91/1102/DTR	91/1128/RVC

Full information on the voting for the approval of this technical report 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.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Electronic products including components nowadays are designed to satisfy the demands for miniaturization, high functionality and environmentally friendly products. Various types of degradation occur in the electronic products used in the field. Appropriate measures are required to mitigate such degradation from the standpoint of reliability assurance. A study has been carried out to develop the understanding of the phenomenon and has proposed test methods for electrochemical migration with the purpose of suppressing the migration in products used in the field.

This Technical Report is related to electrochemical migration including conductive anodic filament (CAF). Specifically, it explains:

- the preliminary test: the steady state temperature humidity test, the temperature humidity cycle test, the unsaturated pressurized vapor test, the saturated pressurized vapor pressure test, the dew condensation cycle test and the water drop test;
- the insulation resistance measurement method: manual measurement, automatic measurement, a dielectric characteristics method, and an AC impedance method. Moreover, the difference between the measurement while the specimen is kept in the testing environment and not taken out of the chamber for measurement, and the measurement of the resistance of a specimen while it is taken out of the test chamber, and the merit of an automatic measurement are also described;
- the equipment used for analysis, the observation method of a failure part, and examples which are used for analysis.

This Technical Report generates a number of benefits for the user:

Usefulness — the user can examine the electrochemical migration test in a short time, and can use it as an indicator of exact analysis.

Test method selection — since for the user the test method which responds to the operating condition of the equipment or the purpose is clearly demonstrated, comparison of test condition becomes easy. Compared to the measurement resistance of a specimen while it is taken out of the test chamber after the test chamber is return to the standard atmosphere condition, the measurement in the test chamber by automatic measurement does not experience the environmental change of a specimen at the time of measurement, and since continuous measurement can be carried out, the resistance change and failure time can be grasped correctly.

Avoidance of trouble — by observing the notice on the test, the user can avoid a trouble and carry out test and analysis efficiently.

ELECTROCHEMICAL MIGRATION IN PRINTED WIRING BOARDS AND ASSEMBLIES – MECHANISMS AND TESTING

1 Scope

This Technical Report describes the history of the degradation of printed wiring boards caused by electrochemical migration, the measurement method, observation of the failure and remarks to testing in detail.

2 Electrochemical migration

NOTE Electrochemical migration is sometimes called ion migration. In this technical report electrochemical migration/ion migration will be referred to as migration.

2.1 Operation failure of electronic and electric equipment

It is known that failures caused by various degradation phenomena occur in electric and electronic products while they are used in the field. Causes of such failures are classified in Figure 1. The causes may be classified into: electric, thermal, mechanical and electrochemical origins. They are entwined with each other. The environment in which equipment is used also affects the generation of failures.

Growth of an electrically conducting filament caused by migration will short-circuit two conductors when a bias voltage is applied between them and will lead to a malfunctioning in the equipment.

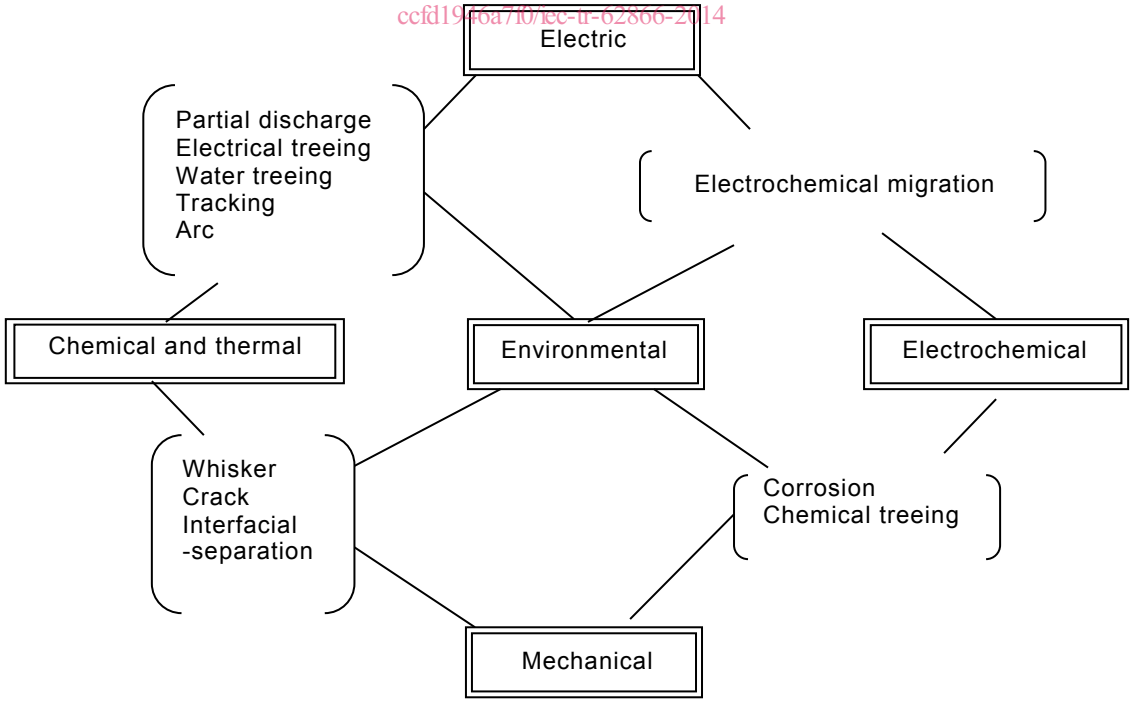

Figure 1 – Main causes of insulation degradation in electronic equipment

2.2 Name change of migration causing insulation degradation and nature of the degradation

2.2.1 History of naming with migration causing insulation degradation

Migration causing insulation failure had been called “ion migration” in Japan. A change of the definition of the phenomenon resulted in a change of name to “electrochemical migration”, but the name of “ion migration” is sometimes still used. The following description is the history of the change of name.

The first report on insulation failure was made in 1955, where the failure caused by the migration of silver atoms was reported and the phenomenon was called “silver migration”. It was also found that other metal atoms, including Pb and Cu, caused similar insulation failures, and so the phenomenon was called “metal migration”. The term “electromigration” was used as a general term for the phenomenon, and has been used for a long time in the IPC test method, IPC-TM-650:1987, 2.6.14A.

It was found since the latter half of the 1960s that interconnection failures in semiconductor devices were serious problems as the current flowing through a conductor significantly increased. This phenomenon was also called “electromigration”. The opening of a conductor was caused by the movement of metal atoms due to an increased current density, which produced dense and sparse layers within the conductor and resulted in a break of the conductor.

IPC changed the name of the phenomenon to “electrochemical migration” in its technical report IPC-TR-467A, and developed a new test method, IPC-TM-650:2000, 2.6.14C, which ISO adopted as ISO 9455-17. IEC 60194 which provides the terms and definitions for printed board design, manufacture and assembly, still uses the term “electromigration”. However, the name should be changed in the near future.

NOTE IPC-9201A uses and defines both electromigration (EMg) and electrochemical migration (ECMg).

References: 1) KOHMAN G. T., et al. *Silver migration in electrical insulation*, BSTJ 34 299, 1955
2) POURBAIX, M., *Atlas d'Equilibres Electrochimiques*, Gauthier-Villars et Cie ed., 1963

2.2.2 Process of degradation by migration

Good insulation between electrodes may be maintained in the application of DC voltage between electrodes on a printed wiring board of electronic equipment, as long as the electrodes are isolated by an insulating material of a high resistivity. If the insulating material absorbs moisture and the insulation resistance decreases, residual ionic contaminants in the insulating material or ions in the absorbed moisture will become active and metal atoms in the material will be ionized. Metal ions dissolve from the metal electrodes, either from an anode or a cathode, into the moistened electrolyte. Ions are transferred through the electrolyte by the electric field force. Metal ions (migration) move to an electrode and then educe in the form of dendrite. The dendrite bridges the neighbouring conductor electrode. The generation of (electrochemical) migration is described in 2.3.

2.3 Generation patterns of migration

Migration begins in the anode by dissolving as metal ions by an electrochemical reaction. There are two cases of this phenomenon as shown in Figure 2. In the first case, the reduction of ions into metal atoms or chemical compound molecules occurs somewhere in between the electrodes. In the second case, the reduction of metal ions occurs when the ions reach the cathode.

The first case is observed when the insulating material still maintains a high resistance to the order of 10^8 Ω or higher. The second case is often observed in HAST (highly accelerated temperature and humidity stress test), where the insulation resistance is reduced by the presence of dew, solder resist or cover layer on the insulation surface.

The difference in these two cases of migration seems due to the difference in the degree of easiness of movement of the metal ions. The second type of migration becomes dominant when

the apparent resistance decrease exists and the metal ions can move more easily than in the first case, while the first case is dominant when metal ions resolve from the anode but cannot move easily in the insulation. The change of one mechanism to the other in the migration is not an independent phenomenon but is simply due to the difference in insulation resistivity of the electrolyte material between electrodes.

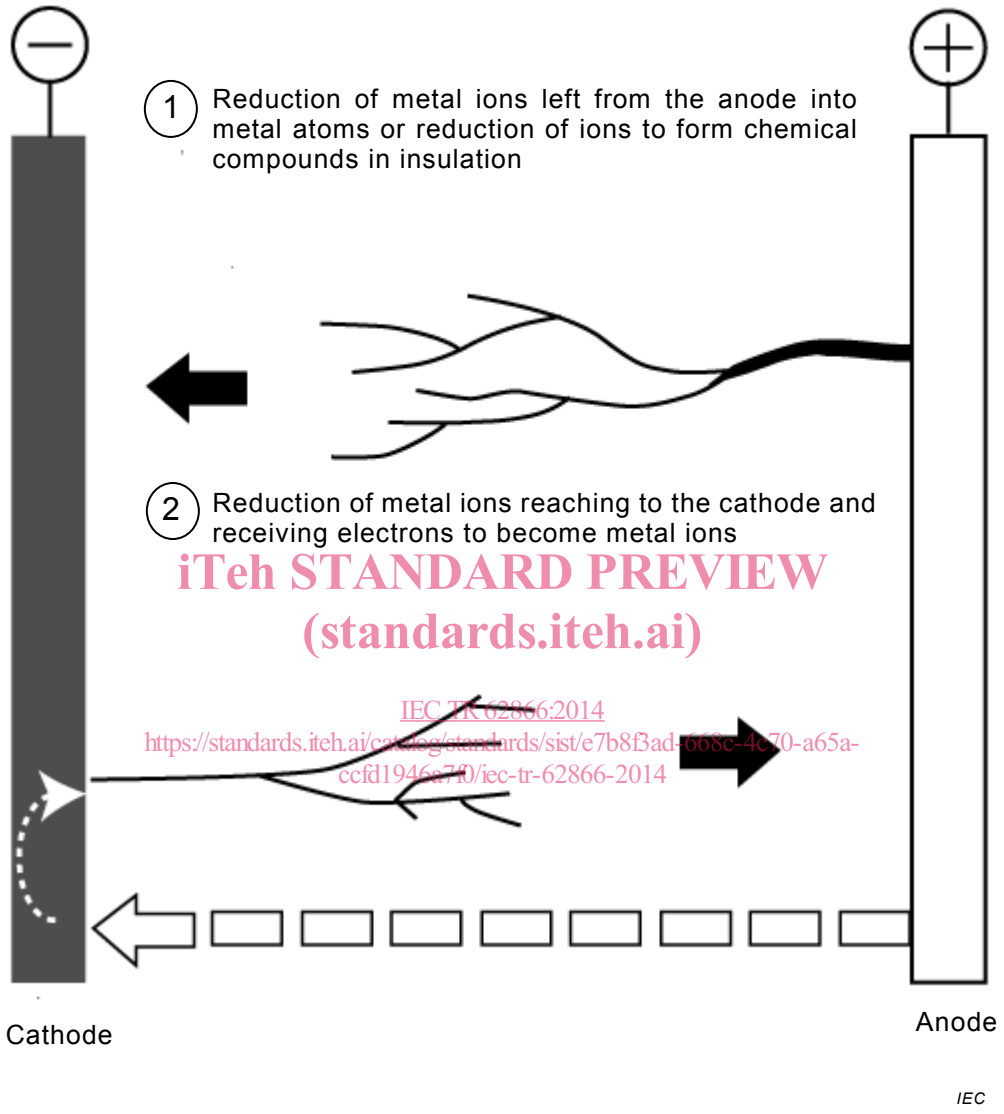

Figure 2 – Generation patterns of migration

3 Test conditions and specimens

3.1 Typical test methods

the main test method for migration is shown in Table 1.

Table 1 – Standards for migration tests

Items	Humidifying conditions	Duration and bias	Document no.
Steady state Temperature/ humidity test	40 °C ± 2 °C 93 % ± 3 %RH	168^{+24}_{0} h 500 h ± 48 h 1 000 h ± 96 h	IEC 60068-2-78
	60 °C ± 2 °C 93^{+2}_{-3} %RH	168^{+24}_{0} h, 500 h ± 48 h 1 000 h ± 96 h	IEC 60068-2-78
	85 °C ± 2 °C 85 % ± 3 %RH	168^{+24}_{0} h, 500 h ± 48 h 1 000 h ± 96 h	IEC 60068-2-67
Temperature/ humidity cycle test	Relative humidity: 90 % to 98 % 80 % in rising and falling period 1) Exposure to humidity followed by exposure to cold. 2) Exposure to humidity not followed by exposure to cold	As agreed between user and supplier About 1 000 h DC voltage of 30 V to 50 V is usually specified	IEC 60068-2-38
Unsaturated pressurized vapour test	110 °C ± 2 °C, 85 % ± 5 %RH 120 °C ± 2 °C, 85 % ± 5 %RH 130 °C ± 2 °C, 85 % ± 5 %RH	96/192/408 $^{+2}_{0}$ h 48/96/192 $^{+2}_{0}$ h 24/48/96 + $^{+2}_{0}$ h	IEC 60068-2-66
	130 °C ± 2 °C 85 % ± 5 %RH	96 h	JESD22-A110-B
Saturated pressurized vapour test	121 °C, 205kPa (100 %RH)	2 h, maximum 8 h No voltage applied	JESD22-A102-C
	Pre-treatment (205kPa), 30 min Then 260 °C solder immersion		IPC-TM-650:1994, 2.3.16.1C

Condition	Zone				JPCA ET 09
	t_1	t_2	t_3	t_4	
1	5 °C/ 60 %RH	≤ 20 s	25 °C/ 90 %RH, 20 min	≤ 15 min	
2	0 °C, 25 min	≤ 20 s	30 °C/ 90 %RH, 20 min	≤ 15 min	
3	–5 °C, 30 min	≤ 20 s	35 °C/ 90 %RH, 20 min	≤ 15 min	