Evaluation of Organic Coatings with Electrochemical Impedance Spectroscopy

Part 3: Protocols for Testing Coatings with EIS

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In Parts 1[1] and 2[2] of this Series, we discussed the technology of applying electrochemical impedance spectroscopy (EIS) to organic coatings on a metallic substrate such as aircraft, marine, or industrial maintenance coatings. This article describes several experimental protocols to evaluate these coatings with EIS. These experimental protocols differ primarily in the process used to stress the coating and accelerate the degradation of the coating.

There is no standard recipe for an EIS-based evaluation program that is guaranteed to work for every coating in every environment. This may come in time and, indeed, a standard for EIS evaluation of coatings is under development at ASTM and ISO.[3] However, EIS can be employed in a variety of ways to evaluate virtually any coating.

It may be useful to think of EIS as a very sensitive detector that provides a snapshot of coating status. However, a single EIS measurement of an organic coating tells you nothing. To measure coating lifetime or performance, the coating must be stressed to bring about its failure. By making periodic EIS measurements during the stress process, a rate of coating failure can be estimated and a series of coatings may be ranked.

Even though some publications discuss the determination of the time-to-failure of a coating, this may be an unrealistic goal. There are too many variables that separate us from this "Holy Grail," most of which are not related to EIS. A more achievable objective is to use EIS in an experimental program that results in a performance ranking of a series of coatings for use in a specific environment.

The nature of the stress applied to the coating is, of course, very important in several aspects. The experimental design to prompt the failure of the coating must (1) simulate the service environment the coating will encounter and (2) it must not change the failure mechanism.[4]

To use EIS to evaluate a specific coating system, (1) place the coated sample in an environment designed to accelerate the degradation of the coating, (2) measure the EIS curves over time, and (3) identify an "index" that tracks coating quality. The index could be the Coating Capacitance or the Pore Resistance, for example. The index can be very simple or more complex and we will look at several examples in this article. Unfortunately, all coatings do not fail in the same way; so there is no universal index for assessing coating quality with EIS.

The complex nature of coatings is no surprise to coatings scientists. A coating system may consist of the metal substrate, surface pretreatment, a primer, and one or more topcoats. Results can vary depending on types of coatings, thickness, number of layers, surface treatment, and the nature of the metal substrate.

EXPOSURE TESTS

For the purposes of this discussion, an "exposure test" implies a testing period equivalent to a typical standardized cabinet or atmospheric test. This may be as short as 15–30 days or as long as several years.

EIS and Atmospheric Exposure Tests

For the ultimate in coatings evaluation, atmospheric exposure is still the "gold standard." Every other test is an attempt to simulate the results of atmospheric tests. The problem with atmospheric tests, of course, is that they require a long, long time. Nothing can accelerate the deleterious effects of atmospheric exposure, but EIS can observe the deterioration of the coating long before visual defects appear.

Measure the EIS curve periodically during the exposure period. Place the sample in contact with the electrolyte in an electrochemical cell and measure the open-circuit potential (Eoc) as a function of time. The electrolyte can be chosen to simulate the particular atmospheric conditions of the exposure test. Run the EIS experiment when the sample has reached a steady state, signaled by a stable value of Eoc. Most computerized EIS instruments can measure the stability of Eoc. You can run the experiment when the stability is better than 0.1 mV/sec.

Immersion and Measurement of Impedance Magnitude at 0.1 Hz

The most straightforward use of EIS to characterize coatings is to immerse the sample in an electrolyte and periodically measure the impedance spectrum. This approach is exemplified by Gray and Appleman,[5] who developed a method to determine the barrier protection properties of coatings. Samples were immersed in 5% NaCl solution, scaled, and placed in an oven at 65°C to accelerate attack. The panels were removed from the oven at 1, 4, 7, 14, and 28 days and the EIS curve was run. (See Figure 1.)

The limiting impedance at low frequency is equal to the sum of Pore Resistance (Rpore), the Polarization Resistance (Rp), and the Solution Resistance (Rs). Rp and Rpore are ini-

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Testing Of Organic Coatings

Zeno W. Wicks, Jr.,Frank N. Jones,Socrates Peter Pappas,Douglas A. Wicks

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Testing of Organic Coatings Norman I. Gaynes,1977 *Hardness Testing of Organic Coatings* P. Fink-Jensen,International Union of Pure and Applied Chemistry. Applied Chemistry Division,1964 **Hardness Testing of Organic Coatings. Prepared for the Subcommittee on Testing Procedures of the Organic Coatings Section, Applied Chemistry Division. (Reprinted from Pure and Applied Chemistry, 1965. Vol. 10, No. 3.).** P. Fink Jensen,1965 **Paint and Coating Testing Manual** , High-Performance Organic Coatings A S Khanna,2008-07-09 Paint coatings remain the most widely used way of protecting steel structures from corrosion This important book reviews the range of organic paint coatings and how their performance can be enhanced to provide effective and lasting protection The book begins by reviewing key factors affecting the success of a coating including surface preparation methods of application selecting an appropriate paint and testing its effectiveness It also discusses why coatings fail including how they degrade and what can be done to prevent these problems Part two describes the main types of coating and how their performance can be enhanced including epoxies polyester glass flake fluoropolymer polysiloxane and waterborne coatings The final part of the book looks at applications of high performance organic coatings in such areas as reinforced concrete pipelines marine and automotive engineering With its distinguished editor and international team of contributors High performance organic coatings is a valuable reference for all those concerned with preventing corrosion in steel and other metal structures Reviews the factors affecting the success of a coating Describes the main types of coating and how their performance can be enhanced including epoxies polyester and waterborne coatings Examines applications in such areas as reinforced concrete pipelines and marine engineering *Corrosion Control Through Organic Coatings* Amy Forsgren,2006-04-25 Choosing the most suitable coatings for structures such as bridges and building supports can extend the service life of that structure significantly Corrosion Control Through Organic Coatings discusses the most important variables in the testing selection and application of heavy duty organic corrosion protection paints The book addresses the maintenance and restoration of older infrastructure and industrial plant as well as coatings for new structures made from various types of steel The author Amy Forsgren examines the mechanisms of aging and deterioration caused by ultraviolet light condensation temperature and chemical reactions She also provides a complete description of composition of anti corrosive organic coatings including pigments binders and additives Ms Forsgren suggests which corrosion tests provide the most useful information on coating performance and corrosion protection Several chapters review the advantages and disadvantages of of different surface preparation methods In addition the author considers the environmental impact of various coatings and recognizes health hazards posed by volatile organic compounds VOC s toxic or hazardous pigments such as lead and silica dust exposure She also offers recommendations for providing safe working environments for personnel handling surface preparation Integrating engineering aspects and corrosion expertise with paint formulation knowledge and

surface chemistry Corrosion Control Through Organic Coatings provides unique coverage of the most advanced treatments for extending the life span of heavy duty metal structures today *Corrosion Control Through Organic Coatings* Ole Øystein Knudsen,Amy Forsgren,2017-04-28 Corrosion Control Through Organic Coatings Second Edition provides readers with useful knowledge of the practical aspects of corrosion protection with organic coatings and links this to ongoing research and development Thoroughly updated and reorganized to reflect the latest advances this new edition expands its coverage with new chapters on coating degradation protective properties coatings for submerged service powder coatings and chemical pretreatment Maintaining its authoritative treatment of the subject the book reviews such topics as corrosion protective pigments waterborne coatings weathering aging and degradation of paint and environmental impact of commonly used techniques including dry and wet abrasive blasting and hydrojetting It also discusses theory and practice of accelerated testing of coatings to assist readers in developing more accurate tests and determine corrosion protection performance

Organic Coatings Zeno W. Wicks, Jr.,Frank N. Jones,Socrates Peter Pappas,Douglas A. Wicks,2007-03-15 Third Edition brings acclaimed textthoroughly up to date with the latestorganic coatings technology Organic Coatings Third Edition is an unparalleled reference and text for organic coatings technology and its myriad applications It begins with discussions of key principles of coatings then thoroughly explores raw materials physical concepts formulations and applications Scientists engineers and paint formulators all gain a deeper understanding of the principles underlying the technology and learn how to use these principles in the development production and application of organic coatings The four authors all leading industry experts offer a unique approach to the topic that correlates the empirical technology of coatings with the underlying science This Third Edition has been completely revised and updated to reflect numerous changes in the field including changes driven by increasing pressure to lower VOC emissions reduce energy requirements and eliminate potential health hazards from organic coatings components In addition the authors have developed new material to make the text more accessible for scientists and engineers first entering the field as well as for students taking coatings courses At the same time the hallmarks that distinguished the two previous editions have been retained including Troubleshooting guidance for coatings scientists and technologists Clear differentiation between established principles and hypotheses requiring further research Precise definitions of coatings industry terminology Extensive references to the current literature Hundreds of figures that help readers visualize key concepts and techniques Whether you are just entering the field of organic coatings and need a broad overview or you are an experienced professional who needs a sophisticated reference you can depend on Organic Coatings to give you the information and answers you need Permanence of Organic Coatings G. G. Schurr,American Society for Testing and Materials. Subcommittee D01.43 on Coatings for Power Generation Facilities,American Society for Testing and Materials. Committee G-3 on Durability of Nonmetallic Materials,1982 *Proceedings of the Symposium On Corrosion Protection by Organic Coatings* Martin W. Kendig,Henry Leidheiser,1987 **Permanence of Organic Coatings** G. G.

Schurr,1982 *Organic Coatings* Frank N. Jones,Mark E. Nichols,Socrates Peter Pappas,2017-08-29 The definitive guide to organic coatings thoroughly revised and updated now with coverage of a range of topics not covered in previous editions Organic Coatings Science and Technology Fourth Edition offers unparalleled coverageof organic coatings technology and its many applications Written by three leading industry experts including a new internationally recognized coatings scientist it presents a systematic survey of the field revises and updates the material from the previous edition and features new or additional treatment of such topics as superhydrophobic ice phobic antimicrobial and self healing coatings sustainability artist paints and exterior architectural primers making it even more relevant and useful for scientists and engineers in the field as well as for students in coatings courses The book incorporates up to date coverage of recent developments in the field with detailed discussions of the principles underlying the technology and their applications in the development production and uses of organic coatings All chapters in this new edition have been updated to assure consistency and to enable extensive cross referencing The material presented is also applicable to the related areas of printing inks and adhesives as well as areas within the plastics industry This new edition Completely revises outdated chapters to ensure consistency and to enable extensive cross referencing Correlates the empirical technology of coatings with the underlying science throughout Provides expert troubleshooting guidance for coatings scientists and technologists Features hundreds of illustrative figures and extensive references to the literature A new internationally recognized coatings scientist brings fresh perspective to the content Providing a broad overview for beginners in the field of organic coatings and a handy reference for seasoned professionals Organic Coatings Science and Technology Fourth Edition gives you the information and answers you need when you need them *Report* United States. Office of Scientific Research and Development, Proceedings of the Symposium on Advances in Corrosion Protection by Organic Coatings David Scantlebury,Martin W. Kendig,1989 Moisture control in buildings Heinz R. Trechsel,1994 **Fifth International Symposium on Advances in Corrosion Protection by Organic Coatings** M. Kendig,David Scantlebury,2010-07 The papers included in this issue of ECS Transactions were originally presented at the the Fifth International Symposium on Advances in Corrosion Protection by Organic Coatings held at Christ s College Cambridge on September 14 18 2009 *Adhesion Measurement of Films and Coatings, Volume 2* Kash L. Mittal,2014-07-30 This book documents the proceedings of the Second International Symposium on Adhesion Measurement of Films and Coatings held in Newark NJ October 25 27 1999 Since the First Symposium Boston 1992 there had been considerable activity in devising new more reliable and more efficient ways to measure adhesion of films and coatings which resulte **Handbook on Paint Testing Methods** H. Panda,2010-10-01 Paints and their allied products like varnishes enamels pigments printing inks and synthetic resins protect assets from corrosion These are increasingly being used in automotive engineering and consumer durable sectors Paint testing can be done in a number of different ways The fact of the matter is that many industries use several different paint testing methods in order to ensure

accurate results Paint should be tested in a wet form for particular properties but also in the dry form Testing of paints generally falls into three categories testing of the raw materials testing of the finished product and performance testing using accelerated weathering and other simulation type methods of evaluation Coatings technologists deal with interfaces of all classes gas liquid as in an aerosol spray liquid liquid as in an emulsion gas solid as in a dry pigment before its immersion in a vehicle liquid solid as in a pigment dispersion and solid solid as when the crystal faces of two different pigment particles are in tight contact Paint scientists are particularly interested in the formation of liquid solid interfaces that are stable in the package that is in the permanent replacement of the air at the air solid interface of the pigment by the vehicle to give the liquid solid interface of the dispersion In coatings and similar products the criteria for best performance particulate ingredients inorganic organic extender and metallic flake pigments and dispersed phase of latexes depends on the size and shape of particles composing the particulate materials The purpose of paint testing is to help and ensure that the minimum requirements for ingredients and material characterization are met by the manufacturer on a batch basis and to help ensure that the formulated product will provide satisfactory performance in the environment Handbook on Paint Testing Methods explains about aspect of gloss specular glass sheen contrast gloss absence of bloom gloss distinctness of image gloss specular gloss evaluation specular reflectance geometric considerations instrumentation goniophotometers specular glossmeters basic factors producing hiding power refractive indexes of white pigments refractive indexes of organic pigments films for testing preparation of films for test pigments and extenders metallic flake pigments latexes methods for determining particle treatment of data particle size with light microscope etc This handbook elaborates the different testing methods of paints with an understanding of the various tests that can be performed on product performance This handbook will be very helpful to its readers who are related to this field and will also find useful for upcoming entrepreneurs existing industries technical institution etc TAGS Paint and Coating Testing Paint Adhesion Testing Paints Coatings Materials Testing Paint Testing Methods Paint Testing Equipment Coating Testing Methods Paint Testing Commercial Paint Testing Paint Industry in India How to Start Paint Industry in Small Scale Specular Glass Hiding Power Basic Factors Producing Hiding Power Hiding Power of Colored Pigments Van Eyken Anderson Method Hiding Power Versus concentration for Titanium Pigments Formulation of Paints from Predetermined S Values Back Factors Producing MC and TS Spatula and Muller Methods Laboratory Ruller Mill Laboratory Ruller Mill Npiri Method for Colored Pigments Tappi Method of Colored Pigments Tintograph ASTM Method for White Pigments Npiri Method for White Pigments NJZ Method for Zinc Oxide and Titanium Dioxide Dupont Method for Titanium Dioxide Reynolds Constant Volume Method Centrifuge Methods for Specific Gravity of Pigments Paint Testing Procedure Test Methods for Paints Methods For Testing Paints Method for Cellulose Derivatives Band Viscometer Bubble Viscometer Gardner Holdt Bubble Viscometer Surface Tension Measurements Shadow Method Tilting Plate Method Displacement Cell Method Surface Energetics Particle Size Measurement Oil Absorption of Pigments

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