Charge Decay Test in Material Analysis

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Introduction

Currently there are not too many reliable methods available for charge decay measurements. Mr. John Chubb wrote an interesting article about existing test methods in 2002: "There are several methods for the measurement of 'charge decay' described in 'standard' documentation and in published literature. The methods of measurement are very different and many of the methods do not provide the information likely to be expected by uninitiated/unskilled users and are susceptible to the construction of the materials tested." [1]

Two different test methods are presented in IEC 61340-2-1: "The first method determines the dissipation of charge deposited on the surface of the material by a corona discharge. The resulting decrease in surface potential is observed using a field meter or equivalent equipment." [2]

"The second method determines the dissipation of charge from a charged plate through an object under test by applying potential to the metallic plate, disconnecting the voltage source and observing the decrease in potential of the plate by means of a field meter or other equivalent equipment. This method is applicable to measurement of charge dissipation via products such as finger cots, gloves and hand tools." [2]

Charge plate monitor

A Charge plate monitor (CPM), is designed to provide quantitative measurements of the effectiveness of air ionizers. There are several types of CPM in a market. Initial charge depends on the selectable voltage and capacitance of a charge plate. According to ANSI/ESD STM 3.1 [3] a size of the plate is 15.24 cm x 15.24 cm and total capacitance is 20pf. Charge to be neutralized is then 20 nC while potential is set to 1000 V.

CPM is also an excellent educational tool for the demonstration of electrostatic phenomena, such as induction charging, voltage suppression, the difference of potential, triboelectric charging, and electrostatic fields. It is also widely used for the evaluation of relatively conductive ESD-protective items, but there are several reasons, why CPM should not be used for material analyses.

In material analyses the sample is often placed on the plate, while connection area is the largest possible. The physics of the junction between the sample and metal plate is complicated: a voltage and current dependency, breakdown field strength, avalanche, tunneling and polarization affect charging and charge decay properties.

If the sample is homogeneous and conductive enough, and contact resistance between the sample and metal plate is relatively low, CPM gives reasonable results which make sense. That is the reason why people still use CPM in material analyses although the measurement problems are well known and discussed during past thirty years.

However, charge decay measurements are typically needed when resistivity measurements become challenging related to low current measurements. In this case CPM does not provide help, but it does cause errors in measurements.

“This approach may be useful for assessing how quickly charge may be removed from a conducting item in contact with a material - such as a person standing on flooring. It does NOT, however, measure the ability of a material to dissipate charge on its own surface.” [1]

Electric field and capacitance

A floating object in space has certain ability to keep charges. The ability to hold charges depends on the medium and dimensions of objects. Electric field and potential between objects are proportional to the magnitude of charge. Therefore all objects, such as charging and grounding electrodes, affects the electrostatic behavior of the sample.

Electrostatic field between oppositely charged conductive parallel plates is uniform and perpendicular to the plates.

$$C = \frac{Q}{V_{ab}} = \varepsilon \frac{A}{d} \qquad (1)$$

Uniformly charged insulating sheet has half of the electrostatic field compared to the same charge density of conductive material.

$$E = \frac{\sigma}{2\varepsilon_0} \qquad (2)$$

In a case of CPM, a sample is much closer to a charge plate than a ground plane, so it is obvious that capacitive effect cannot be ignored, especially if contact resistance is significant compared to the resistivity of the sample. Capacitance between the sample and metal plate affects potential of the plate. The net charge of the metal plate does not change similarly with electric potential of the plate as often thought.

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Electric charge, potential and capacitance

Electric potential is sometimes confused to charge. For example a common sentence the object has “1000 V charge” doesn’t mean anything else but mistake. Electric potential *V* is potential energy per unit charge. Electric charge *Q* is one coulomb [C], which can be expressed as an ampere in a second [As]. In case an object has known capacitance we are able to calculate charge:

$$Q = V\frac{\varepsilon A}{d} = CV \qquad (3)$$

Charge distributions are described by charge density:

$$\lambda = \frac{Q}{L}\ \left[\frac{C}{m}\right] \qquad (4) \qquad \sigma = \frac{Q}{a}\ \left[\frac{C}{m^2}\right] \qquad (5) \qquad \rho = \frac{Q}{V}\ \left[\frac{C}{m^3}\right] \qquad (6)$$

Mobility of charge

Conductors are materials that permit electric charge to move easily within them. Charges move easily in conductors. Electric field inside a conductor is zero in electrostatic situation. Most metals are good conductors.

Depending on surface charge density, insulating objects do not typically have significant mobile charge, but they may have remarkable immobile charge. Sometimes the only way to neutralize an insulator in practice is ionization.

Triboelectrification (Contact electrification)

Contact electrification refers to the charging process, which occurs when two objects are connected and separated from each other. Net charge accumulates efficiently when the pair of objects is a “conductor insulator” or an “insulator insulator”. A “conductor conductor” pair charges also, but due to a complete back flow as a result there is no net charge accumulation while the pair is separated.

Charging by ionizing

Corona discharge is often used as a charging method and it is useful in many cases, but initial delay between corona charging and measurement may cause faulty conclusions. On the other hand, such an efficient ionization may not be expected to see in nature. Corona ionization may also cause physical changes on the surface to be ionized.

Charging by High Voltage Connection

A direct HV connection is sometimes confused with Contact electrification. The principle of contact charging in charge decay measurement is inconsistent. Insulators cannot be charged up by the direct connection. Otherwise they won’t be insulators.

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In case of an inhomogeneous sample only conductive and dissipative parts of the sample can be charged up during the charging period but insulating areas remains without charges. In nutshell, only mobile charges can be transferred by the direct connection.

If the sample is electrostatic dissipative and homogeneous, a charging period has to be at least as long as a discharging period. However, sometimes it is difficult to see if all the transferrable charges have been moved before switching the charging mode to the discharge mode.

Contact resistance

A metal surface does not provide the lowest contact resistance with non metal surfaces, as often misunderstood. From the material analyses point of view contact resistance causes systematic errors in measurements. The lowest contact resistance, the most reliable result. Therefore metal connections such as alligator clips are not accepted in electrostatic measurements. Conductive rubber is often chosen for reducing systematic error.

Sample under test

The shape and size of object may also prevent the usage of standard test setup. For example FTMS 101 method 4046 can be used only if the sample is planar, homogeneous, and electrically dissipative [4].

Characterization of charge decay

There are a great number of parameters which affects charge decay. It is important to understand what parameters need to be considered in test setup. It is obvious that charge decay should not be measured without knowing how much charge will be transferred during the measurement. In addition size of the sample, charge density, contact surfaces, contact resistance, charging method all have to be considered carefully before making the measurement.

Characterizing materials in a changing electrostatic field [5]

Cascade Metrology introduced the new approach to material analyses in 32nd annual EOS/ESD Symposium 2010. In this study response of the surface potential and transferred charge was simultaneously recorded while the sample was influenced by an impulse of electrostatic field.

A sample is placed parallel with an induction plate and grounded from one side through the integrating charge meter. The sample holder is adjustable for different sizes of samples. Distance between the sample and induction plate can be adjusted depending on the desired capacitive coupling. The induction plate is connected to the output of a high voltage amplifier, which is controlled by a function generator. An electrostatic influence of the sample is measured with the electrostatic voltmeter and a charge meter. An analog output of the voltmeter is connected to CH1 of oscilloscope. A charge meter is connected to CH2.

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Principles of characterization are presented in Figure 1. A high voltage square pulse is applied to the induction plate. Influenced potential is measured from the opposite side of the sample. A response of the surface potential and transferred charge was simultaneously recorded while the sample was influenced by an impulse of electrostatic field.

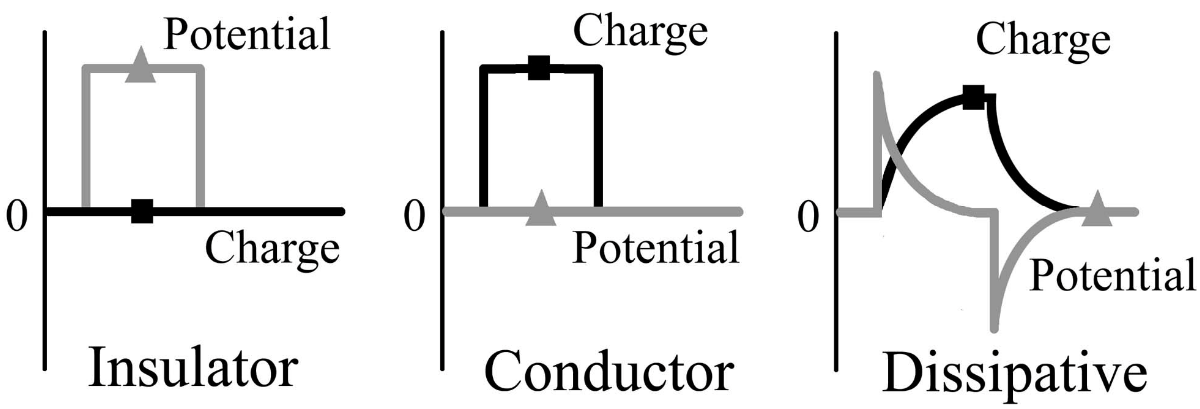

Figure 1 Characterizing electrostatic properties in a changing electrostatic field

References

[1] Comments on Approaches for Measurement of Charge Decay, John Chubb 25.1.2002

[2] Standard IEC 61340-2-1:2002 Measurement methods - Ability of materials and products to dissipate static electric charge

[3] Standard ANSI/ESD STM3.1: 2006 Ionization

[4] Federal Standard FTMS 101C, Method 4046.1, October 8, 1982

[5] Characterizing Slowly Dissipative Materials, Viheriäkoski, T.; Laajaniemi M.; Niemelä S.; Hillberg J.; Tamminen P.; EOS/ESD Symposium, 2010 32nd, Page(s): 1 – 6

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