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SURFACE RESISTIVITY MEASUREMENTS OF ELECTROSTATIC DISCHARGE PROTECTIVE MATERIALS FOR DIFFERENT RELATIVE HUMIDITY LEVELS

BY

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Abstract. The paper is focused on surface resistivity measurements of electrostatic discharge productive materials. Our experimental studies presents the measurement results for nine kinds of electrostatic discharges (ESD) productive materials, having the relative humidity range from 20% to 80%. We used in our attempt the 6517A Electrometer and 8009 Resistivity Test Fixture, in accordance with the requirements of ASTM D-257 standard. We extracted conclusions concerning the influence of the relative humidity on the surface resistivity.

Key words: surface resistivity; electrostatic charge and control.

1. Background

Electrostatic discharge (ESD) represents the transfer of electrical charge between two bodies at different potentials, through direct contact or through an

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induced electrical field. Hereby, an ESD event is a two-body system. The two main sources of ESD events come from people and equipment. The current waveforms produced can be different in shape, duration and peak current (Vinson *et al*., 2003). ESD can modify the electrical characteristics of a semiconductor device, degrading or destroying it or may upset the normal operation of an electronic system, causing equipment malfunction or even failure. ESD damage is usually caused by any of the following events: ESD to the device, ESD from the device or induced field discharge (www.esda.org, 2001). The electric and electronic industry has standar-dized three main models related to ESD events, models which are based on the charge storage location: Human Body Model (HBM), Machine Model (MM) and Charged Device Model (CDM). Each model is described by several standards who defines the equivalent circuit model and, also, the testing and calibration characteristics (Vinson *et al*., 2003).

Among all the electrical materials, an important category is represented by materials for protection and control of any ESD phenomena, where the electrostatic charges can dissipate over their surfaces or their volumes. Called ESD materials or ESD protective materials, these materials can be grouped, according with their electrical conductivity, into several categories, as follows: ESD anti-static materials, ESD static-dissipative materials or ESD conductive materials. A basic electrical parameter for these ESD protective materials is resistivity (surface or volume resistivity), which strongly depends on the relative humidity (RH) of the environment. The water quantity absorbed into ESD protective material will influence the carrier trapping characteristics of the material or could contribute free charge carriers (Paasi *et al*., 2001). Surface resistivity, ρ_s , [Ω/square] is defined in the literature as the ratio of DC voltage, U, per unit of length, L, to the surface current, I_s , per unit of width, l. The most used test method for measuring static control material is Surface Resistivity ASTM-D-257, method implemented for resistivity measurements of insulating materials (Weitz, 1998).

In our paper we have studied the surface resistivity parameter as a function of RH (20%…80% RH range) for nine kinds of ESD materials, that are used in electrical and electronical departments, on protection of human personnel or technical process and technologies.

2. Procedure, Technique and Measurement Instrumentation

The measurement configuration is presented in Fig. 1, where surface resistivity will be measured by applying a voltage potential across the surface of the material sample, then measuring the associated current.

The basic instrumentation used in the surface resistivity measurements involves

a) *6517A Electrometer Keithley*, with surface and volume resistivity measurements, DC voltage measurements from 1 μV to 210 V, DC current measurements from 10 aA to 21 mA, charge measurements from 10 fC to

2.1 μC, and resistance measurements from 10 Ω to 210 Ω. The model 6517A includes Built-in V-Source (the 100 V tange provides up to 100 V at 10 mA and the 1,000 V range provides up to 1,000 V at 1 mA), data storage, built-in math functions, filtering and built-in test sequences.

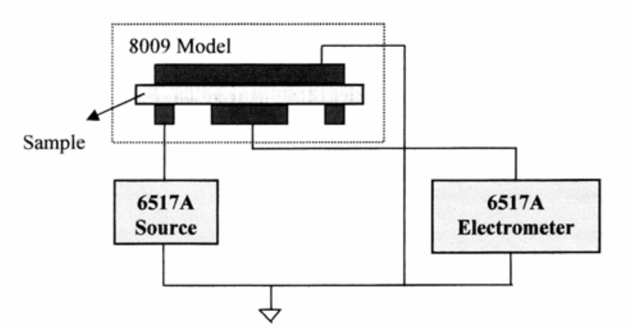

Fig. 1 – General configuration.

b) *The model 8009 Resistivity Test Fixture*, designed for measuring the surface and volume resistivity of materials. Also, this model is designed to ensure complete electrostatic shielding and can accommodate samples from 64 mm to 102 mm in diameter. The working voltage is max. 1,000 V and the test current is max. 0.1 A.

Fig. 2 – Experimental arrangement.

c) *RH 520 Humidity and Temperature Recorder Extech Instruments*, with graphical and digital display. This recorder can measure the RH in 10%…95% range and temperature in –20.0°…140.0°F range. He has an internal storage memory, for max. 49,000 recordings.

Fig. 2 shows the measurement system for surface resistivity, using the instrumentation presented above.

The model 6517A electrometer performs and displays automatically the surface resistivity

$$\rho_s = RK_s \,, \quad (1)$$

where: ρ_s is the surface resistivity, R – resistance, [Ω], $K_s = P/g$ – geometry coefficient, with P – the effective perimeter of the guarded electrode, [mm], and g – distance between the ring electrode and the guarded electrode, [mm] (*Volume and Surface Resistivity…*, 2001).

The electrometer is connected with a low noise cable to the resistivity chamber.

The electrification time used (defined as the total time in which the specified voltage is applied to the material sample) for ρ_s measurements is 60 sec.

Four our measurements we used nine different types of materials namely:

1. ESD cardboard (with 0.30 mm thickness).
2. ESD paper (with 0.10 mm thickness).
3. ESD bag (with 0.07 mm thickness).
4. ESD textile material, for human protection (with 2.80 mm thickness).
5. Cotton (with 1.50 mm thickness).
6. Textolite (with 0.58 mm thickness).
7. Polystyrene (PS – with 2.00 mm thickness).
8. Polyethylene (PE – with 1.10 mm thickness).
9. ESD plastic P/N 317B (with 1.00 mm thickness).

All these material samples were prepared in accordance with the design requirements of the model 8009 Resistivity Test Fixture, with specific dimensions (the samples were prepared with 24…48 h before taking measurements and with a maximum thickness of 3.2 mm and a range of 64…102 mm diameter). The measurements were performed at a RH = 20%, 40%, 60% and 80%, in adequate condition of temperature. Surface resistivity, for each sample, was measured several times and the results were recorded after an average of ten measurements. The method or technique used in these measurements was the method of 6517A Electrometer and 8009 Resistivity Test Fixture, with the RH 520 Humidity and Temperature Recorder.

3. Measurements Results

In Fig. 3 is presented the measurement of surface resistivity as a function of RH and the Table 1 shows the obtained results. The Fig. 4 presents the surface resistivity variation of tested materials as a function of RH. The measurements were performed with high precision, according to the requirements of the standards.

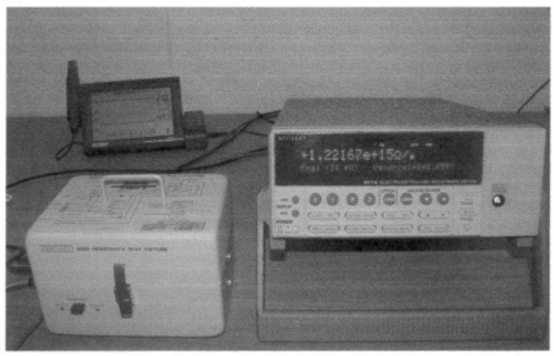

Fig. 3 – Measurement of surface resistivity.

Table 1

The Obtained Measurement Results for Surface Resistivity, ρ_s, as a RH Function

Material under test	Surface resistivity ρ_s, [Ω/square]			
	RH = 20%	RH = 40%	RH = 60%	RH = 80%
ESD cardboard	2.729×10^{12}	6.913×10^{11}	1.197×10^{12}	2.801×10^{10}
ESD paper	8.751×10^{12}	1.315×10^{12}	6.808×10^{11}	2.713×10^{10}
ESD bag	6.153×10^{13}	1.202×10^{13}	5.513×10^{12}	2.315×10^{12}
ESD textile	7.592×10^{9}	2.003×10^{9}	7.816×10^{8}	1.213×10^{8}
Cotton	9.781×10^{13}	7.158×10^{12}	2.117×10^{11}	7.953×10^{10}
Textolite	2.215×10^{13}	3.556×10^{12}	8.862×10^{11}	2.103×10^{11}
Polystyrene (PS)	8.931×10^{15}	2.183×10^{15}	5.509×10^{14}	1.151×10^{13}
Polyethylene (PE) with PET	2.012×10^{15}	6.915×10^{14}	5.965×10^{13}	1.007×10^{13}
ESD plastic P/N 317B	3.058×10^{14}	5.831×10^{13}	3.420×10^{12}	4.813×10^{11}

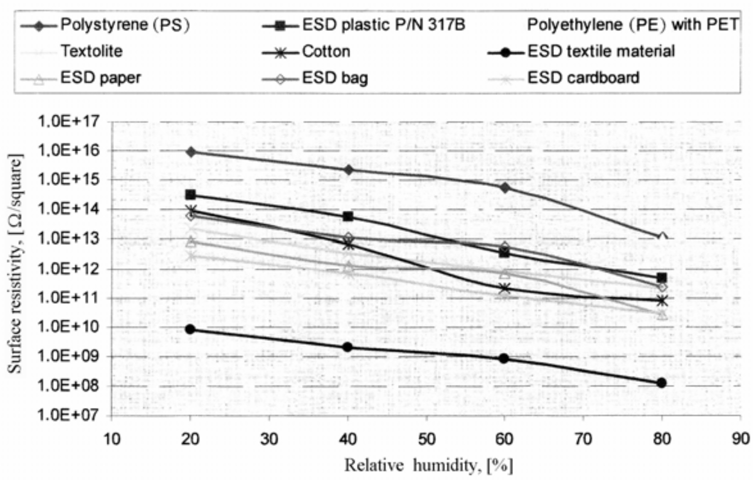

Fig. 4 –Tested materials surface resistivity variation *vs*. RH.

According with the results indicated in the diagram we can observe that the surface resistivity for all the studied ESD materials increases exponentially with the decreasing of the RH.

4. Conclusions

Electrostatic discharge phenomena (ESD phenomena) arises due to the static charge accumulation. ESDs can create significant damages or can generate some negative effects (like electronic sensitive equipments affection, electrical and electronic circuits damages, etc.) bringing it up to the degradation or destruction of these devices. Thus, it is necessary to avoid or diminish the accumulation of electrostatic charges to avoid the apparition of ESD phenomena. Thereby, an important significance shows a class of electrical materials, called *electrostatic discharge protective materials*. These materials present a basic role for necessary protection against ESD events.

In this study were carried out a number of measurements – for parameter surface resistivity – on nine different kinds of such materials, for various levels of relative humidity. Resistivity measurements are useful to evaluate the ability of the material to provide charge dissipation and electrostatic shielding. From the obtained results we can observe that with the increasing of relative humidity environment test decreases the surface resistivity of the materials. The variation of surface resistivity for tested materials *vs.* the relative humidity (RH) is represented in the diagram from Fig. 4. Also, we can say that for a relative humidity range between 0…40%, some of ESD protective materials tested can have insulating properties and may become insulating materials. The importance of maintaining a decent level for the relative humidity in an ESD protection area has been underlined.

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MĂSURAREA REZISTIVITĂŢII DE SUPRAFAŢĂ A MATERIALELOR DE PROTECŢIE ESD PENTRU DIFERITE NIVELE ALE UMIDITĂŢII RELATIVE

(Rezumat)

Lucrarea de faţă este conturată pe problematica măsurării rezistivităţii de suprafaţă pentru o serie de materiale de protecţie ESD. Studiile şi cercetările realizate prezintă rezultatele unor măsurători effectuate pe nouă tipuri diferite de materiale de protecţie ESD, pentru domeniul de umiditate relativă cuprins între 20%…80%. Metoda utilizată pentru măsurători foloseşte electrometrul 6517A şi celula de măsură 8009 Keithley, în conformitate cu cerinţele standardelor în vigoare. Astfel, conform măsurătorilor, se poate observa că pentru toate tipurile de materiale supuse testării, caracteristica rezistivitate–umiditate relativă este puternic influenţată de umiditatea relativă a mediului (rezistivitatea de suprafaţă a materialelor scade odată cu creşterea umidităţii relative).