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THE INFLUENCE OF ELECTROSTATIC DISCHARGE (ESD) ON THE QUALITY OF ELECTRONIC COMPONENTS IN THE AUTOMOTIVE INDUSTRY

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Abstract: *The burgeoning integration of large-scale integrated circuits in modern electronic techniques has transformed various spheres of human life. However, these circuits' low power consumption and delicate structures render them vulnerable to electrostatic discharge (ESD), releasing charges that can inflict significant damage within microseconds. This paper delves into the obstacles and solutions aimed at achieving Zero Defect Quality in the automotive sector, particularly focusing on electronic products and testing perspectives. It emphasizes the necessity of ESD protection in production and quality laboratories, highlighting the critical role of ESD flooring and footwear compatibility. Testing methodologies, including electrical resistance and charge generation assessments, are essential for ensuring ESD mitigation in automotive electronics production.*

Key words: *Electrostatic discharge (ESD), electronics, ESD protection, quality in automotive, over-stressing, testing perspective, zero defect quality*

1. INTRODUCTION

With the ongoing advancements in information and communication technology, electronic techniques utilizing large-scale integrated circuits have become pervasive in various aspects of human life. Many integrated circuits and semiconductors used in electronic devices are characterized by their low power consumption and minuscule structures, rendering them susceptible to over-stressing. When subjected to electrostatic discharge, these devices can release charges in the range of several amperes to dozens of amperes within nanoseconds to microseconds.

The instantaneous power generated during discharge can reach hundreds of kilowatts, leading to high-intensity damage to integrated chips and semiconductor devices, with discharge energies reaching several millijoules. Hence, when designing electronic circuits and systems, the primary focus lies on ensuring the reliability and security of the circuit and system, with electrostatic discharge being the predominant cause of equipment damage.

The paper will outline the obstacles and remedies aimed to ensure and achieve Zero Defect Quality in automotive sector especially for electronic products, focusing on testing perspectives.

Taking into consideration that automotive electronic products are very sensitive to ESD, this phenomenon will be studied in, and most importantly the influences of ESD.

Analysis the reason why ESD loses its efficacy and explores the methods to solve the ESD related problems. The first concern revolves around protecting the ESD-sensitive areas, where the electronic products are manufactured and manipulated in the testing area must be considered. The studies were made on testing laboratories and production lines of electronic automotive products. Both simulation and measurements results indicate the enhances its ESD resistance capability.

2. ELECTROSTATIC DISCHARGE (ESD)

2.1 Electrostatic discharged phenomenon

The substance in nature can acquire or lose electrons through certain process, this kind of

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electric charge is called static electricity. The accumulation of positive or negative charges can cause potential difference with the surrounding environment. The charge transfer phenomenon produced by discharge path between different potentials is called electrostatic discharge phenomenon, ESD for short.[1]

2.2 Failure modes of electrostatic discharge (ESD)

Two main reasons of ESD caused failure are: electrical failure and or thermal failure. A large amount of heat can conduct in melting of metal line interconnections or the formation of hot spots, thereby precipitating thermal failure. ESD electric failures encompass a range of damaging phenomena, including oxide punchthrough, dielectric breakdown, and electric damage to components, like short circuits. These failures occur when the discharge generates high currents and voltages, overwhelming the device's protective measures. Additionally, ESD events can produce electromagnetic interference (EMI), further complicating the reliability of electronic systems.

There are three ESD caused failure modes:

1. Hard failure: material damage or destroy;

2.Soft failure: temporarily logical function change;

3. Potential failure: Time dependence failure [2]

ESD protection desires rapid static discharge capacity, therefore the protection structure will not be damaged during the static discharge process, ESD protection structure should also has a strong power-resistant ability, which is the most fundamental requirement. [2]

In recent years, studies electric failures have been identified in automotive parts more frequently than before. By considering the number of failures recorded at 1 Defective Part Per Million (DPPM) we can expect to have 1 failure at an automotive car part recorder every hour. Sources of Electrically Induced Physical Damage (EIPD) and failure returns from customers. [3][4]

Based on this information the automotive sector aims to the “Zero Defects” strategy regarding the electric failures generated by Electrostatic Discharge (ESD). The strategy may be implemented by taking some measures in ESD protection on production side, quality side (laboratories, quality check, etc.), logistic, warehouse, etc.

3. ASPECTS OF THE IMPORTANTCE OF ESD PROTECTION AND ESD FLOORS IN ATUOMOTIVE INDUSTRY

This study will aim to assess the importance of ESD protection on production lines and quality laboratories, where the products are more manipulated compared with other zones.

In the studied factory form automotive sector, one major requirement is to have the ESD floors, more specifically floors that consist of materials engineered to dissipate static electricity safely.

Electrostatic Discharge flooring protects electronics from damage caused by static electricity, which accumulates when people are walking on it. The ESD floors components that give the electrical conductivity and create an electrical pathway from the walking surface to ground are carbon, graphite or metal-coated particles which are distributed throughout the flooring.

ESD flooring standards are established with a focus on the compatibility between the ESD flooring and the footwear employed within the environment. While certain ESD floors are designed not only to dissipate charges but also to inhibit charge generation, not all exhibit this dual functionality. Specifically, these floors aim to mitigate the accumulation of static electricity as individuals traverse the area. Consequently, it becomes imperative to ascertain the specific type of footwear that will be utilized within the space to ensure optimal performance of the ESD flooring system.

In the selection process of an appropriate ESD floor, it is essential to conduct comprehensive testing to assess both electrical resistance, as per the STM7.1 standard, and charge generation, in accordance with the STM97.2 standard. [5]

The characteristics that an Electrostatic Discharge floor should have, are the following:

- To have the relevant electrical code and to be respected in the utilization for floor;

• Automotive industry standards for body voltage electrical charging and electrical resistance;
• Electrostatic Discharge protective footwear that will be used in the production hall or other locations form the factory;
• Having the measurement results for resistance (STM 7.1) and charge generation (STM97.2).

Anyways a floor still can generate enough static and may be conductive to damage the electronic automotive products. For this the following tests and measurements have been performed at the production hall and laboratory from the quality department.

3.1 ESD Testing and measurement in the studied automotive company

The first test performed was carried out in the quality laboratory to measure the resistance that the ESD floor from the laboratory has and at the same time the values of the system resistance. On second test was used the production hall floor where the electronic products are manufactured.

The following terms will be used on the measurements.
Rgp = resistance of the floor to ground point;
Rs = resistance of the system.

Table 1

Laboratory 1 - 2022

RH:	43%		
Temperature:	23° C		
Tested points	**Rgp (MΩ)**	**Rs (MΩ)**	**Limit<1GΩ 900MΩ**
1	0,77	51,20	900,00
2	0,79	51,10	900,00
3	0,78	54,02	900,00
4	0,84	63,25	900,00
5	0,76	62,30	900,00
6	0,81	64,30	900,00
7	0,78	61,55	900,00
8	0,87	50,24	900,00
9	0,86	58,13	900,00
10	0,78	56,20	900,00

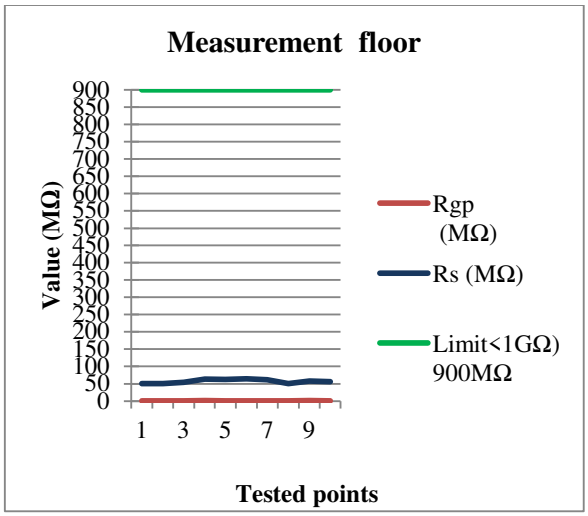

Fig. 1. ESD floor measurement in laboratory 1 for year 2022

Table 2

Laboratory 1 - 2023

RH:	47%		
Temperature:	23° C		
Tested points	**Rgp (MΩ)**	**Rs (MΩ)**	**Limit<1GΩ 900MΩ**
1	0,47	31,55	900,00
2	0,46	35,30	900,00
3	0,45	32,20	900,00
4	0,41	29,25	900,00
5	0,51	34,20	900,00
6	0,55	32,26	900,00
7	0,51	31,31	900,00
8	0,60	34,28	900,00
9	0,59	36,25	900,00
10	0,57	33,24	900,00

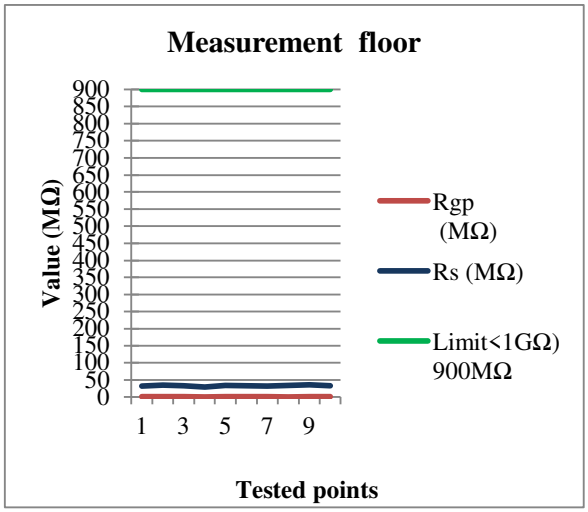

Fig. 2. ESD floor measurement in laboratory 1 for year 2023

The Rgp value represents the resistance of floor to ground point. The measurements is made by connecting an electrode to the floor and to the ground point and by using the special measurement equipment the values are determined.

The values of Rs are measured from a certain point of an employee related to the ground point of the floor by having an electrode connected to the ground point and one electrode on the person who performs the test.

Production hall ESD floor test:

The same test was performed for the production area.

Table 3

Production hall 1 - 2022

RH:	45%		
Temperature:	25° C		
Tested points	**Rgp (MΩ)**	**Rs (MΩ)**	**Limit<1GΩ 900MΩ**
1	0,38	11,50	900,00
2	0,42	9,25	900,00
3	0,49	9,14	900,00
4	0,38	9,60	900,00
5	0,35	7,55	900,00
6	0,52	9,36	900,00
7	0,60	8,50	900,00
8	0,63	10,45	900,00
9	0,43	9,40	900,00
10	0,44	12,05	900,00

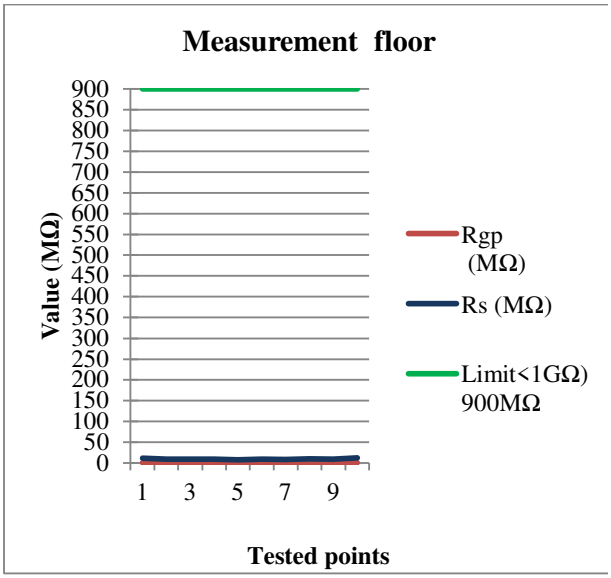

Fig. 3. ESD floor measurement in production hall for year 2022

Table 4

Production hall 1 - 2023

RH:	40%		
Temperature:	25° C		
Tested points	**Rgp (MΩ)**	**Rs (MΩ)**	**Limit<1GΩ 900MΩ**
1	0,47	9,20	900,00
2	0,45	10,51	900,00
3	0,65	8,42	900,00
4	0,52	9,16	900,00
5	0,72	10,42	900,00
6	0,62	14,30	900,00
7	0.80.	14,26	900,00
8	0,65	12,30	900,00
9	0,54	13,15	900,00
10	0,65	15,20	900,00

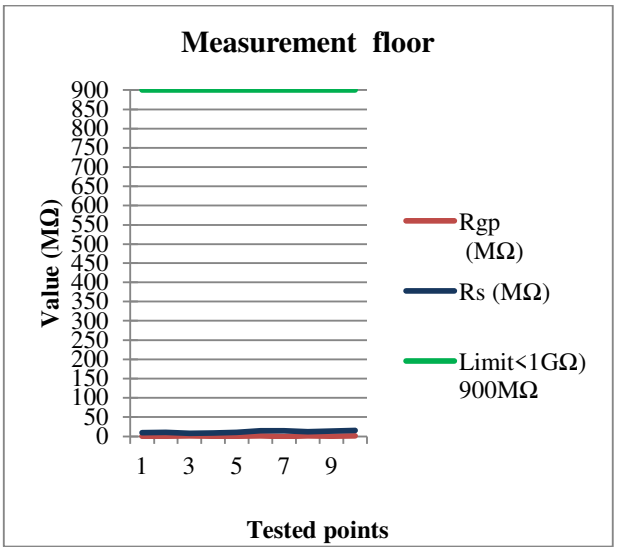

Fig. 4. ESD floor measurement in production hall for year 2023

This test performed for production hall validates the conformity of manufacturing area for electronic products. The results obtained in the test are OK for the existing ESD floor, no critical values were measured.

Walking test have been performed alongside the laboratory area on the EDS floor to measure the electric charge of employes wearing the ESD footwear agreed in the company.

The measurements were performed on the same laboratory area for the year 2022 and 2023.

The scope of the walking test is to measure and determine the electrostatic charge that is caused by employees when they carry out their work by walking on the ESD floor.

Walking test measurements for 2022:

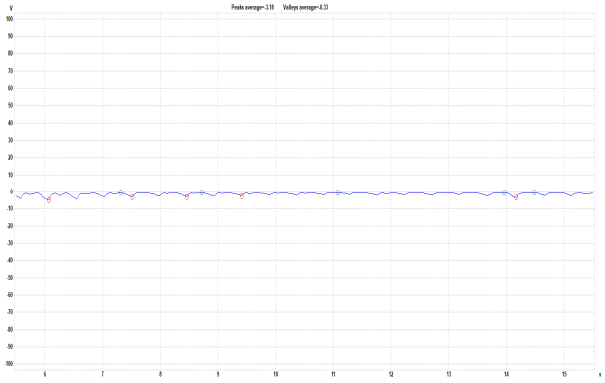

Fig. 5. Walking test 1 – laboratory area for year 2022

Walking test measurements for 2023:

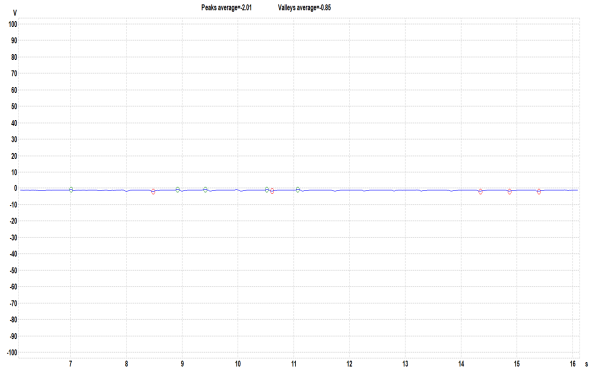

Fig. 6. Walking test 1 – laboratory area for year 2023

The results form the walking tests shows that for both years the ESD floor together with the adequate ESD footwear does not allow the employee to accumulate electrical charging to affect the quality of the electronic products analyzed in the quality control laboratories.

4. CONCLUSION

The study highlights the susceptibility of integrated circuits and semiconductor devices to electrostatic discharge (ESD), which poses a significant threat to the reliability and security of electronic systems, especially in the automotive sector. Through analysis of failure modes, it identifies electrical and thermal failures as the primary consequences of ESD, necessitating rapid static discharge capacity and robust power-resistant capabilities for effective protection. Notably, the automotive industry's adoption of a "Zero Defects" strategy underscores the critical importance of ESD protection measures in production and quality control processes. The investigation emphasizes the role of ESD-resistant flooring and protective footwear in mitigating ESD-induced damage, advocating for comprehensive testing methodologies to assess electrical resistance and charge generation.

The study's findings underscore the imperative of proactive measures to safeguard automotive electronics against ESD-related risks, with particular emphasis on ESD protection in sensitive production areas and quality laboratories.

The research underscores the critical importance of understanding ESD phenomena and implementing effective mitigation strategies to ensure the integrity and reliability of automotive electronics amidst the pervasive integration of integrated circuits and semiconductor devices.

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INFLUENȚA DESCĂRCĂRII ELECTROSTATICE (ESD) ASUPRA CALITĂȚII COMPONENTELOR ELECTRONICE DIN INDUSTRIA AUTOMOTIVE

Rezumat: Integrarea în plină dezvoltare a circuitelor integrate la scară largă în tehnicile electronice moderne a transformat diverse sfere ale vieții umane. Cu toate acestea, consumul redus de energie și structurile delicate ale acestor circuite le fac vulnerabile la descărcarea electrostatică (ESD), eliberând sarcini care pot provoca daune semnificative în câteva microsecunde. Această lucrare analizează obstacolele și soluțiile care vizează atingerea calității "Zero Defect" în sectorul auto, concentrându-se în special pe produsele electronice și perspectivele de testare. Se subliniază necesitatea protecției ESD în laboratoarele de calitate și zone de producție, subliniind rolul critic al pardoselilor ESD și al compatibilității acesteia cu încălțămintea. Metodologiile de testare, inclusiv evaluările rezistenței electrice și ale generării de încărcare, sunt esențiale pentru a asigura atenuarea ESD în producția de electronice auto.

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