ESD capability of resistors

§0 Abstract
Various tests are conducted to ensure the reliability of electronic equipment, and one of the most common is electrostatic discharge (ESD) testing, which is performed on a wide range of devices. ESD testing is requested also for individual electronic devices such as resistors in some cases. It is important to note that even with the same test voltage, the waveform and required level of ESD testing varies depending on the required standard. Furthermore, each electronic device has different ESD capabilities. This technical note explains an overview of the fundamentals of ESD testing and the ESD capability of resistors.

§1 What is ESD Testing?
1.1 System-level testing and device-level testing
ESD testing standards for electronic devices are broadly classified into two categories: system-level testing for electronic equipment and device-level testing for electronic devices. Standards for the system-level, such as IEC61000-4-2 and ISO10605, are for evaluating the ESD capability of the entire system by monitoring the devices after the ESD is applied. On the other hand, standards such as JEITA ED4701/302A and ANSI/ESDA/JEDEC-JS-001 are for device-level testing to evaluate the ESD capability of individual electronic devices, such as ICs, resistors, capacitors and others, by checking the failure of the device after the ESD is applied. Table 1 shows the ESD testing standards for each category.

Table 1 ESD testing standards (System-level, Device-level)

Test class.	Testing standard	Test overview
System-level	IEC 61000-4-2, ISO 10605 (Automotive electronics) etc.	Object : Electronics equipment Assumption : ESD from human body while operating an electronic device Output voltage : Max. 30kV
Device-level	JEITA ED 4701/302A, ANSI/ESDA/JEDEC-JS-001 etc.	Object : Electronic device (IC, resistor, capacitor, etc.) Assumption : ESD from electronic device and human body assembling electronic device Output voltage : Max. 8kV

In general, device manufacturers provide evaluation data resulting based on the device-level testing. However, in certain case, the system-level testing is conducted on individual electronic devices to properly assess the ESD capability under the actual usage condition. In such cases, excessive loads may be imposed on the devices, which could lead to device failure. Therefore, when conducting the system-level testing on a device, it is recommended to have the device mounted on an actual PCB along with ESD protection device and incorporated in a chassis.

1.2 Types of device-level testing

Device-level testing is classified into human body model (HBM), which simulates the discharge from the human body, machine model (MM), which simulates the discharge from manufacturing tools and charged device model (CDM), which simulates the discharge due to the charge on the device itself. Resistor manufacturers often provide HBM and MM data. Note that the use of the discharge capacitor and discharge resistor in table 2 does not conform the testing to below standards if the used testing equipment is for the system-level testing based on standards such as ISO10605.

Table2 Standards for device-level testing

Standard		Test condition(ex)
HBM (Human Body Model)	JEITA ED 4701/302A (test method 304A), ANSI/ESDA/JEDEC-JS-001	D.C. (*1)100 pF D.R. (*2)1.5 kΩ
MM (Machine Model)	Eliminated from the latest standard The old standard for reference: EIAJ ED4701/300 (2001, test method 304), JESD22-A115C (2010)	D.C. 200 pF D.R. 0 Ω
CDM (Charged Device Model)	JEITA ED 4701/302A (testing method 305D), ANSI/ESDA/JEDEC-JS-001	Both D.C. and D.R. depend on the device

*1 D.C.: Discharge capacitor, *2 D.R.: Discharge resistor

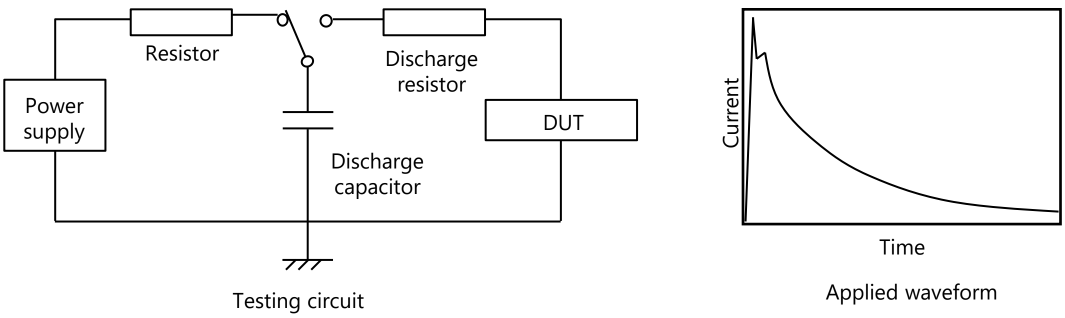

Fig. 1 Testing circuit and applied waveform of HBM

§2 ESD Damage to Resistors

2.1 Effect of ESD on resistance value

Figure 2 shows the effect of the ESD voltage on the resistance value of the general-purpose thick film chip resistors. The ESD testing was conducted on the resistors of the same type and size, nevertheless, the test result revealed that the changing trend of resistance differs by the resistance value of the resistor. For the resistor with relatively low resistance values such as 100 Ω, the resistance increases with the voltage. For the resistors with 1 kΩ, the resistance initially decreases before increasing with the voltage. For the resistors with 10 kΩ or higher, the resistance decreases with increasing the voltage. There is also a difference in the voltage at which the resistance starts to change. In general, resistors with higher resistance values tend to exhibit a decrease in the resistance at lower voltages.

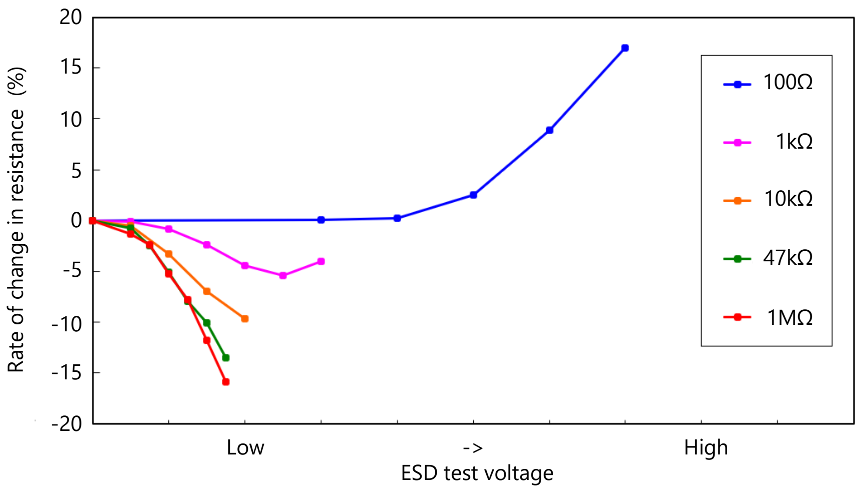

Fig. 2 Effects of the ESD test voltage on the resistance value

As described, resistors of the same type and size can have different levels of ESD capability and different trends of resistance change depending on their resistance values. Consequently, when conducting ESD testing or reviewing the ESD testing results provided by the manufacturer, it is essential to clarify not only the type and size of the resistor, but also the resistance value.

2.2 Mechanism of ESD damage in resistors

This section explains the resistance change of thick film chip resistors caused by ESD. The resistive material consists of insulating materials, such as glass, and conductive materials. The resistive material is printed onto an alumina substrate and sintered at a high temperature. During the sintering process, a reaction layer with semiconductor-like properties is formed at the interface between the glass and conductive materials. The resistance value of the resistor is determined by the proportion of the conductive materials, the insulating materials and the reaction layer. Lower resistance values are resulted from the higher proportion of the conductive materials, while higher resistance values are resulted from the higher proportion of the insulating materials. Figure 3 shows the resistive element of a thick film resistor and its damage modes.

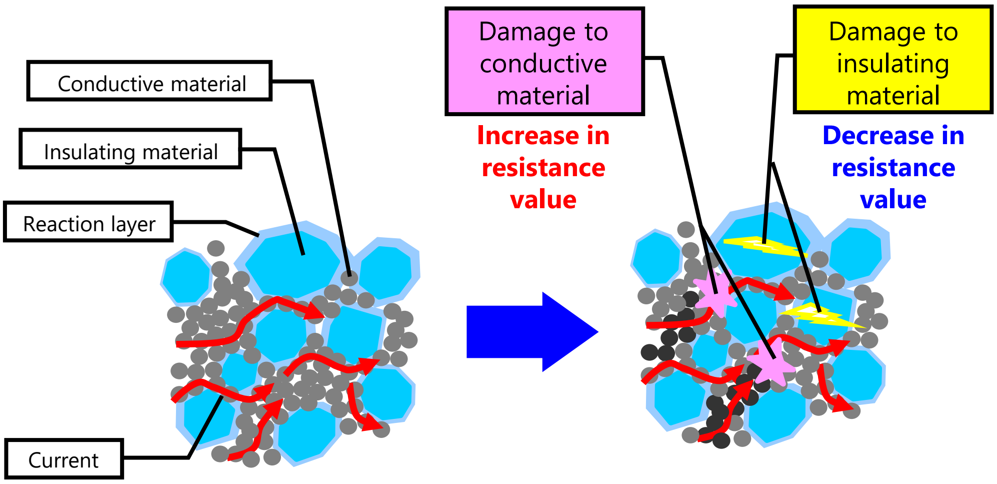

Fig. 3 Conductive path of thick film resistive material and damage modes caused by ESD (image diagram)

When ESD is applied to a resistive element, a large instantaneous current flows through the conductive paths, causing the burnout or melting due to Joule heating, which damages the conductive material, and increases the resistance value. In contrast, when a high voltage (strong electric field) is applied, the insulating material undergoes an insulation breakdown, resulting in a decrease in resistance value. Therefore, when more than a certain amount of ESD is applied to a resistor, the resistance value increases and decreases simultaneously due to the damage of the resistive elements. In the case of relatively low resistance values such as 100 Ω, the conductive material has the significant influence and causes the overall increase in the resistance value. Conversely, in the case of high resistance values such as 10 kΩ, the insulating material has the significant influence and causes the overall decrease in resistance value. As a result, the trends demonstrated in Fig. 2 are produced.

§3 ESD capability of resistors

Figure 4 shows the results of ESD testing on 0603-inch-size (0603) and 1206-inch-size (1206) general-purpose flat chip resistors of 1 kΩ and 10 kΩ. The resistance change is greater for 10 kΩ than for 1 kΩ, which indicates that ESD capability varies depending on the resistance value. Additionally, a significantly larger resistance change on 0603 than on 1206 illustrates that there is also a difference in ESD capability based on size. Therefore, when selecting a resistor, it is important to consider both the size and resistance value to ensure the appropriate ESD capability.

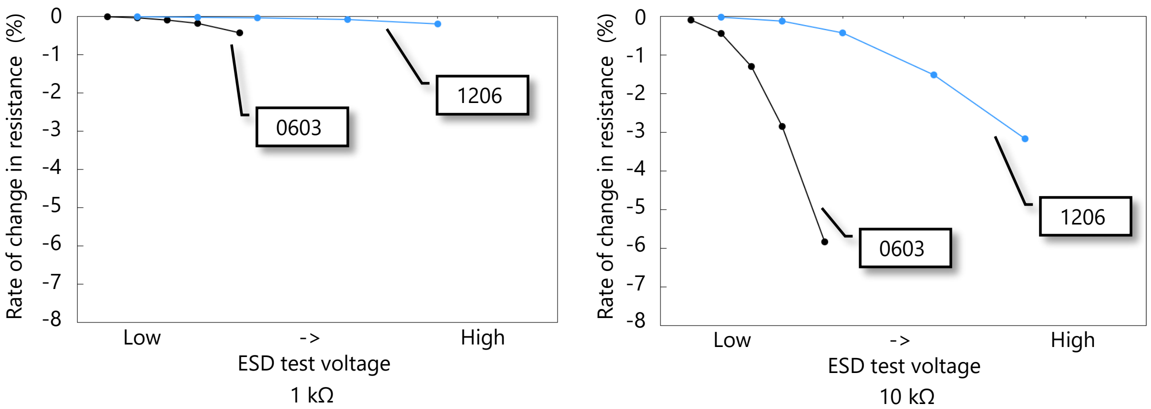

Fig. 4 Comparison of rate of change in resistance during ESD testing(0603 vs. 1206)

If improvement in the ESD capability of a resistor is required, anti-surge products are an effective option. Figure 5 shows the results of ESD testing between the general-purpose 0603 resistor from the previous section and an anti-surge resistor of the same size. It is evident that the change in the resistance is smaller for the anti-surge resistor.

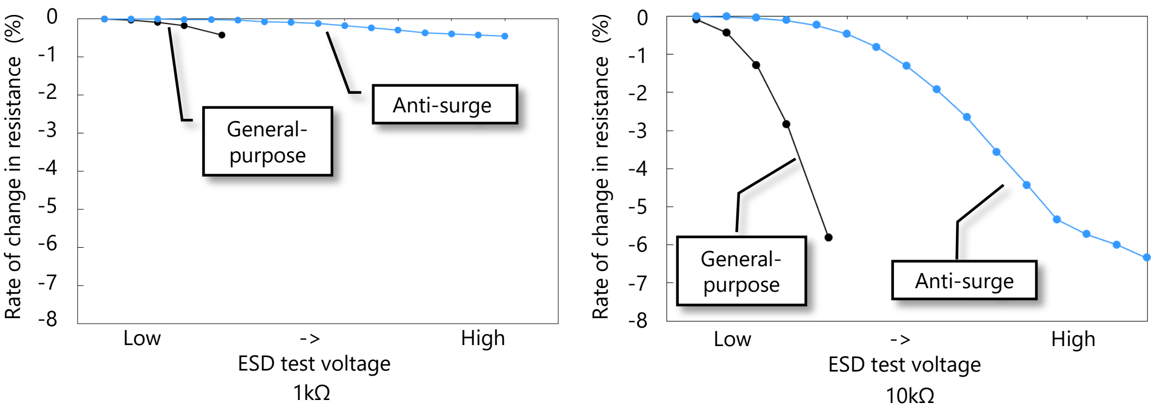

Fig. 5 Comparison of rate of change in resistance during ESD testing(general-purpose vs. anti-surge)

Additionally, the results in Fig. 4 and 5 show that the anti-surge resistor in 0603 product has ESD capability comparable to the general-purpose resistor in 1206. Therefore, the use of anti-surge resistor can be a solution if there is concern about a decrease in ESD capability when replacing with a smaller resistor.

§4 Summary

ESD testing standards include device-level testing which is intended for the manufacturing stage of electronic equipment, and system-level testing which is intended for the actual usage stage of electronic equipment.
The ESD capability of resistors varies depending on their resistance value and size. ESD has a greater influence on the resistance of the resistors with higher resistance values, as well as those with smaller sizes. When considering the replacement with smaller resistors due to the equipment downsizing, it is recommended to take measures such as the use of anti-surge resistors to avoid a possible risk of lowering the ESD capability.
KOA offers various supports including the provision of ESD test results of KOA's products. Feel free to contact us.