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Voltage Coefficient of Resistance

As applications for electronics continue to grow, a wider range of application requirements is a natural evolution. For most applications, paying attention to power ratings, tolerance, temperature coefficient of resistance, and the expected shift of the resistor is enough to ensure good long-term reliability. However, if the application requires high voltage handling, another lesser known parameter known as VCR may become important. But what is VCR and what are the key factors that affect VCR?

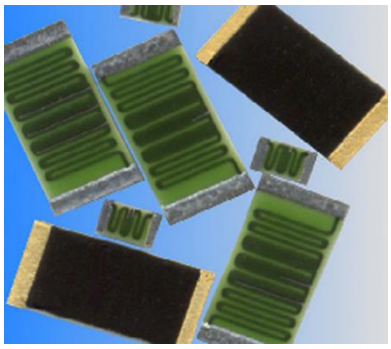

Fig. 1 High Voltage Chip Resistors

VCR

VCR (Voltage Coefficient of Resistance) is defined as the change in resistance over a specified change in voltage. In simple terms, it means how stable the resistance value will be at different voltages. Some design engineers may not realize that VCR even exists, but every resistor has some level of instability over voltage. For low voltage applications, or those where voltage levels are stable, regulated, and predictable, VCR is a non-issue. For other applications such as power delivery systems or test equipment, changes in voltage can lead to unacceptable changes in resistance.

General purpose film resistors, especially those with high resistance values will generally have VCR of ± 10 ppm/V to ± 25 ppm/V or higher. This would mean a potential 1% to 2.5% change in resistance when measuring over a voltage range of 1KV. Resistors with a higher VCR or used in applications with larger voltage swings would see even larger changes in resistance value.

VCR Factors

VCR can be minimized through proper resistor selection and understanding the factors that affect VCR. Resistors that utilize standard thick film deposition processes will have poorer VCR than those that utilize direct writing processes that use a pen. This is due to the improved resistance definition and reduced edge effects. Larger size resistors will have better VCR because lower ohmic value materials may be used to realize the high resistance values.

In the manufacturing process for resistors, it is common to use a laser or mechanical trimming process to adjust the resistance value within the specified tolerance. This is most common for resistance tolerances of 1% or tighter. But trimming the resistive element during the manufacturing process has an adverse effect on the VCR of the resistor. For thick film chip resistors, this calibration trimming of the resistive element will cause microcracks as the thick film materials cool after trimming. This effect is shown in Fig. 2 below. These microcracks cause parasitic impedance changes, increased electrical noise, and increased VCR.

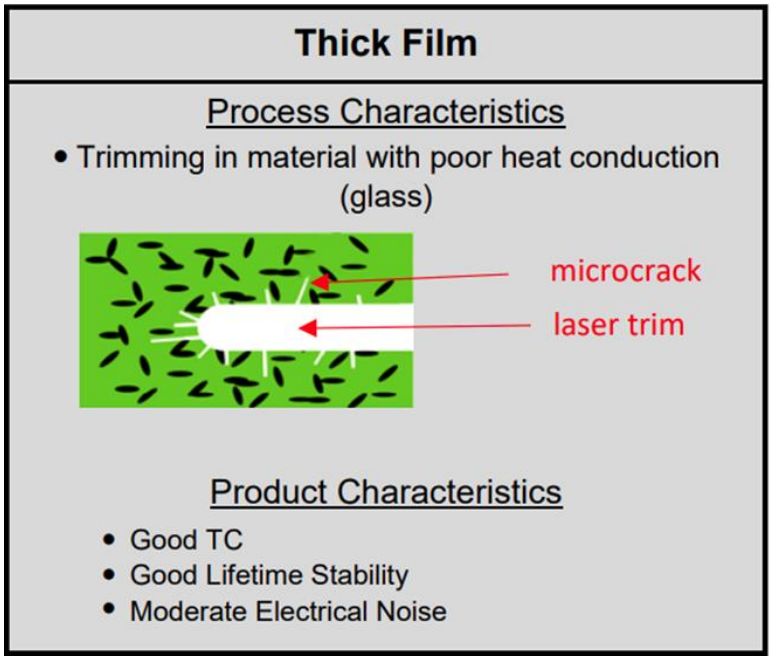

Fig. 2 Thick Film Trimming Process Characteristics

VCR can be optimized with proper design and materials selection. Low VCR resistive materials can improve VCR, but normally this is at the expense of temperature stability in the form of poorer TCR. In general, lower resistance inks will have better VCR also, but it is challenging to achieve higher resistance values with those lower resistance materials. Applying the element via screen printing has limitations in terms of pattern length and resolution which reduces the voltage capability and limits the resistance value range that can be offered. Resistive element deposition with a pen greatly improves the pattern length and definition allowing for the highest resistance values and highest voltage ratings while utilizing lower resistance inks than would be required from a screen printed element.

High Voltage Design with Low VCR Requirements

Beyond the design, materials, and processing improvements that must be done to achieve improved VCR, the other difficulty designers face is that VCR is not generally continually monitored parameter. VCR is a product of consistent and repeatable materials and processing but is generally only verified occasionally or at random intervals. Therefore, if VCR is critical, it is possible to that some resistors in a given manufacturing lot will exhibit higher VCR than expected which could be detrimental to precision high voltage applications. Currently, only the Stackpole HVCR series offers guaranteed VCR due to 100% VCR screening. Furthermore, the HVCR has specific VCR of -2 ppm or -5 ppm depending on size which allows for further precision design choices as opposed to usual VCR specifications which allow positive or negative resistance shifts.

Summary

Understanding VCR and the factors that affect it are important to high voltage applications and test systems. Selecting an untrimmed resistor with the proper element deposition process and in the largest body size will minimize the effects of VCR and provide the best performance over the widest voltage range. If VCR is critical, most high voltage chip resistors currently available will yield performance that may exceed the circuit requirements. Stackpole's HVCR offers guaranteed low VCR performance due to 100% VCR screening.