Stackpole Electronics, Inc.
Resistive Product Solutions

TECHNICAL **ARTICLE**

Designing High Reliability Thin Film Chip Resistors

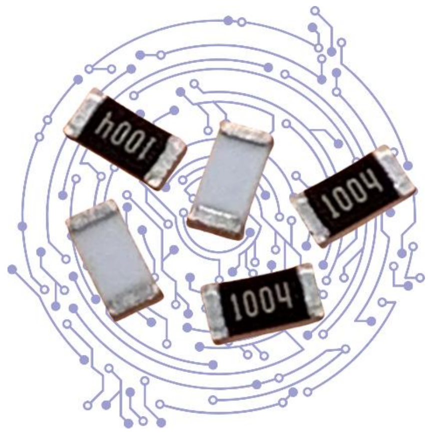

Fig. 1 Precision Chip Resistors

Thin film chip resistors have rapidly gained acceptance as increased electronic content creates greater need for precision resistors. Thin film resistors in 0.1% tolerance and 25 ppm TCR are now readily available in the market.
The predominant technology for most thin film chip resistors is a simple nichrome resistive element. While nichrome resistors provide excellent stability and the capability to achieve precision tolerances and temperature coefficients, there are some limitations and drawbacks.

Recent market developments have shown some applications need a higher level of performance than standard precision thin film resistors. This development has led to design and technology improvements in thin film resistors that have significantly improved the overall stability and reliability, such as Stackpole's RNCE series of thin film high stability precision chip resistors.

Standard Thin Film Materials and Design

Typical thin film resistors currently begin with screen printed thick film inner conductors to provide the termination base. Nichrome resistive elements are then applied in a vacuum sealed chamber through a process called sputtering. This process requires a clean and dust free environment and yields precision resistors that have proven reliability and performance for more than 30 years. After the resistive element is applied, each part is trimmed with a laser to achieve the proper value and tolerance. Once this is complete, the parts are passivated, and the terminations are completed before final testing.

One key limitation of nichrome film elements is they are inherently susceptible to failure by moisture. The effect of moisture intrusion into a sputtered nichrome element is one of two things: corrosion, also known as oxidation, or dissolution, where the resistive element itself dissolves and evaporates. In either case, the resistance value increases and eventually, over time, will cause the resistor to completely open. Another limitation of this structure is that the inner terminations, which are typically a thick film silver material, may be susceptible to sulfur corrosion, which may also lead to increased resistance values or open failures.

Structure:

- CERAMIC SUBSTRATES
  - High purity alumina
  - Improved smoothness
- RESISTANCE LAYER
  - Proprietary metal alloy
  - Enhance moisture resistance
- TOP INNER ELECTRODE
  - AgPd paste
  - High palladium content >1% WT
- PROTECTIVE OVERCOAT
  - Phenolic epoxy resin
  - Double protective layer
- TERMINAL ELECTRODE
  - Nickel barrier
  - Additional C4 outer conductor
  - Tin solder coating

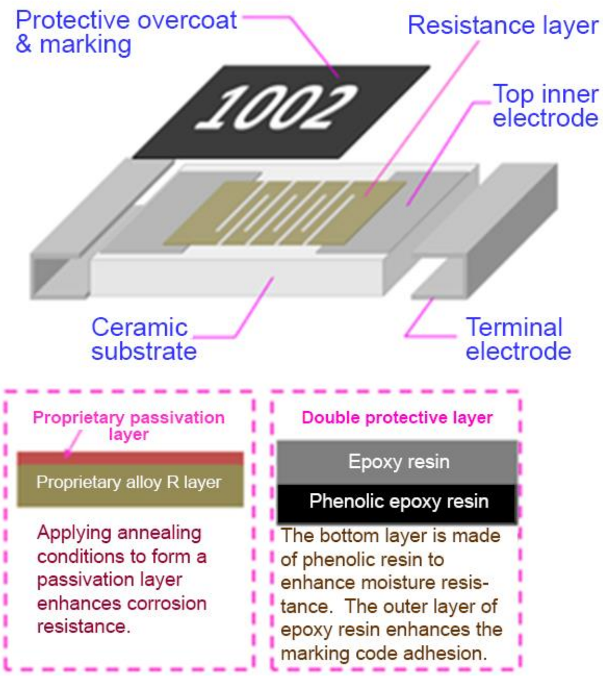

Fig. 2 Robust Thin Film Design Cross Section

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A Unique Robust Thin Film Resistor Design

To achieve significantly better performance, reliability and stability, many design and material aspects must be considered. The substrate base material utilizes a higher grade of ceramic. The higher purity provides a surface with improved smoothness, which helps ensure element uniformity and reduces the frequency and severity of low spots on the substrate. These low spots may collect moisture or other contaminants.

Inner conductor materials are chosen with increased metal content other than silver. These non-silver metals provide proven higher resistance to sulfur corrosion. The addition of an additional auxiliary electrode also improves the resistance to sulfur in that it creates a longer infiltration path for sulfur and an additional connection to supplement the initial inner conductor.

Perhaps the most significant design improvement lies in the resistive element itself. State of the art sputtering systems, with multiple chambers, can apply a thicker material layer. These manufacturing processes are also able to apply different metal alloys that greatly enhance the ability of the element to resist moisture corrosion. These alloys develop a moisture barrier after annealing that is impervious to moisture penetration.

Finally, the protective layer on the element can be significantly improved by using a phenolic epoxy resin as an initial passivation layer under the 2nd and final passivation. Phenolic epoxy layers tend to have better electrical insulation, higher temperature capability, and better flame resistance.

Test	RNCE	Standard Nichrome Thin Film
Endurance / Load Life	+/- 0.1%	+/- 0.2% to +/- 0.5%
Biased Humidity	+/- 0.1%	+/- 0.3% to +/- 0.5%
Temperature Cycling	+/- 0.1%	+/- 0.2% to +/- 0.5%
High Temperature Exposure	+/- 0.1%	+/- 0.5% typical

Fig 3 RNCE vs Standard Nichrome

Superior Proven Test Performance

The improvement in the overall performance of this robust design is impressive. Anti-sulfur testing under the harshest ANSI / EIA-977 test at 105°C, 1000 hours duration yields resistance shifts of less than 1%.

This design and structure enable high temperature operation up to 85°C with operation up to 175°C possible, where most other chip resistors are limited to 70°C for full power and 155°C for operating temperature limits.

Improvement in load life stability is also noteworthy with typical shifts of less than 0.03% after 1000 hours and calculated stability change at 10K hours of less than 0.07%. Biased humidity testing under what is considered one of the harshest biased humidity test conditions, shows resistance changes well within 0.03% as well.

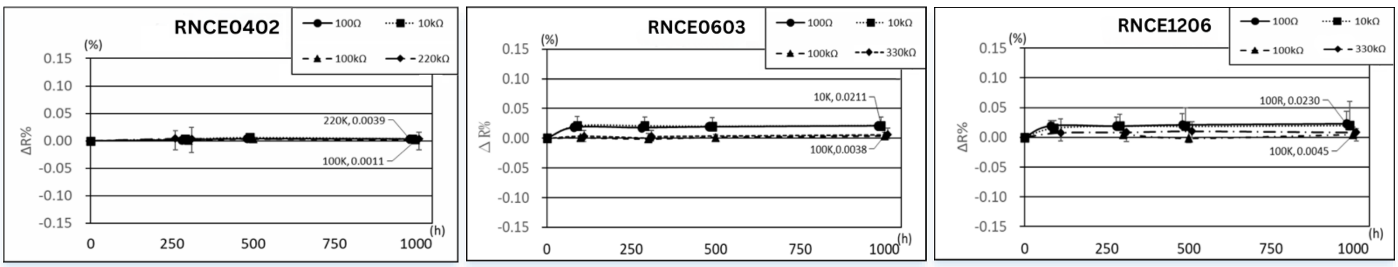

Fig. 4 85°C / 85% RH, 10% Rated Power Biased Humidity Test Results

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Summary

With the proliferation of electronics into a wider range of markets and end products, the need for precision resistors has grown significantly. Some of those markets and end products require long term stability and environmental performance that many current thin film chip resistors cannot support. Stackpole's RNCE series, with the use of robust materials, innovative element design, and additional conductor and passivation layers, provides test proven performance that rivals any thin film product on the market. This enhanced reliability and stability ensures excellent product performance for the long term.