Major Advancements in the Protection of Thin Film Nichrome-Based Resistors with Specialized Passivation Methods (SPM)

Abstract

Nichrome Thin Film have typically been used in applications requiring excellent performance but have exhibited catastrophic failure under harsh moisture environments, unless protected in hermetic packages. Tantalum Nitride resistor films have typically been the film of choice but require performance trade offs for precision application. The advancement in new specialized passivation methods (SPM) now allows for enhanced resistor performance in high humidity applications without complex, costly hermetic packaging or use of tantalum nitride films. This Tech Note is intended to be a comprehensive study with data to demonstrate the advances in specialized passivation methods (SPM) with focus on the test results of a variety of film materials, and to give designers alternatives and explain traditional compromises made. The purpose is to educate the circuit user of Thin Film materials and the benefits of design performance with SPM when harsh environments exist. These benefits are achieved through enhanced passivation control response under harsh conditioning. The paper proves a new concept for design with focus on performance enhancement.

Introduction

Special passivation methods are a multilayer system of applying passivation over moisture sensitive resistor material (see Figure 1). Typically, chip resistors used in applications of high humidity and low power were required to be made of tantalum nitride to avoid catastrophic failure. Nichrome films under the same conditions would shift in value and typically open. When enhanced performance was required under these conditions, Nichrome resistors where put in hermetic packages or not used and electrical performance degraded to tantalum nitride levels. The promotion of these devices in harsh high humidity environments has been limited to tantalum nitride due to historical performance and poor performance of passivations. Over the years, several advances have been made and improved user handling, bake outs after mounting and board PCB coatings have minimized the failure rate levels.

This Tech Note evaluates the difference between resistor films and moisture test requirements to demonstrate that when properly passivated with Vishay's SPM methods, that new performance advancements under harsh conditions can be obtained.

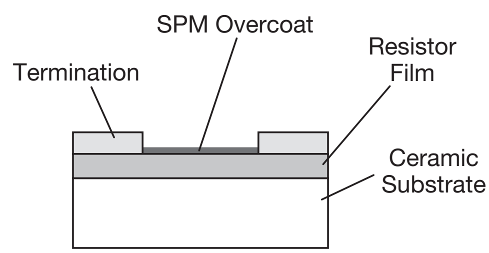


Figure 1. - SPM Construction

TABLE 1 - SPM PROPERTIES		
Melting Point	None	°C
Flammability	SELF extinguishing	
Dielectric Constant	3.3	1 kHz, 25 °C
Coefficient of Thermal Expansion	4.0×10^{-5}	/°C
Surface Resistivity	$> 10^{16}$	Ω
Dielectric Strength	> 300	kV/mm

Moisture Failures

The failure mechanism is an electro-chemical interaction which dissolves the resistive film under powered moisture conditions. Traces are etched until the resistor elements open and fail. The moisture resistance elements open and fail. The moisture resistance of Nichrome depends on the integrity of sealing. The moisture resistance of tantalum nitride depends on the proper thickness of Tantalum Pentoxide coating. Tantalum Nitride resistors will exhibit the same failure mode if pentoxide layers are not controlled or established.

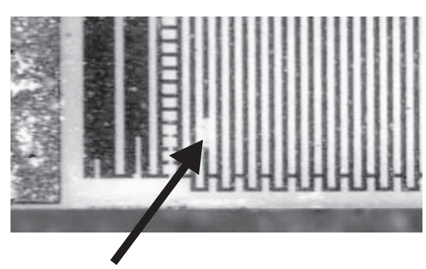


Figure 2. - Electrolytic corrosion caused by reaction of moisture combined with low power on Nichrome resistive element.

Major Advancements in the Protection of Thin Film Nichrome-Based Resistors with Specialized Passivation Methods (SPM)

Figure 3. - 400 x view with transmitted light reveals etched lines causing shift in resistance value.

Resistor Film Sacrifices

Thin Film Chip Resistors are available in either Nichrome resistor film or Tantalum Nitride. The selection of the film can limit the Temperature Coefficient of Resistance (TCR) and the sheet resistivity of the film. Nichrome films offer higher sheet resistivities and can achieve resistance values of two times tantalum nitride for the same surface area.

TABLE 2 - RESISTOR FILMS: THE TCR REQUIREMENT CAN DICTATE THE RESISTOR FILM SELECTION

Resistive Material		NiCr	Ta_2N
Termination	Au	■	■
	Al		■
Standard (sheet resistance ohms per quare)	25	■	■
	50	■	■
	100	■	■
	200	■	
	450	■	
Absolute TCR ppm/°C	100	■	■
	50	■	■
	25	■	■
	10	■	
	5		

Temperature Coefficient of Resistance (TCR) Sacrifices

When traditional films were reviewed and selected based on moisture requirements, the TCR was limited to the properties of that film. Tantalum Nitride films are limited to 25 ppm/°C vs. Nichrome which is limited to 10 ppm/°C. The selection of the film dictates the limits of TCR and can effect the end of life tolerance limits.

TCR is a measure of the rate at which a resistor varies with increasing or decreasing temperature. It is defined as follows:

$$TCR = \frac{R2 - R1}{R1(T2 - T1)} \times 10^{-6}$$

TCR = Temperature Coefficient of Resistance (ppm/°C)
R1 = Resistance at room temperature (Ω)
R2 = Resistance at operating temperature (Ω)
T1 = Room temperature (°C)
T2 = Operating temperature (°C)

Tolerance Sacrifices

Nichrome chip resistors are now available in tolerances to ± 0.02 % vs. Tantalum Nitride chip resistors are available to ± 0.1 %. A difference of ± 0.08 %, on a 1 kΩ value, this equates to a 0.8 Ω difference. When combined with the TCR differences, the guard band on a design can make a significant difference.

Major Advancements in the Protection of Thin Film Nichrome-Based Resistors with Specialized Passivation Methods (SPM)

Methods of Evaluating Moisture

There are four tests typically used to evaluate moisture penetration in the industry and one developed for short term evaluation at Vishay. The conditions of each are as follows:

1. HAST Test (Highly Accelerated Temperature and Humidity Stress test) is a test under two atmosphere pressure at 121 ºC at 10 % rated power for 96 hours.
2. 85/85 moisture test is a test at 85 ºC, 85 % relative humidity under 10% rated power. The test duration is 1000 hours.
3. Military moisture tests MIL Std-202 method 106, modified to a 10 % rated power, test duration of 1000 hours.
4. 46 day moisture test. The test samples are at 40 °C with 90 % relative humidity. The test samples are under 10 % rated power with a duration of 56 days. (1344 hours).
5. Two hour Wet HAST Test Pressure Cooker test. The test is similar to the HAST test except time is limited to 2 hours and the relative humidity is 99 %.

TABLE 3 - EFFECT ON BEGINNING-OF-LIFE CALCULATIONS

Nichrome vs. Tantalum Nitride Chip Resistors			
	Nichrome	**Tantalum Nitride**	**Total Delta**
Absolute Tolerance	± 0.02 %	± 0.1 %	± 0.8 %
TCR (- 55 °C to + 125 °C)	10 ppm/°C (0.0010 %)	25 ppm/°C (0.0025 %)	15 ppm/°C (0.0015 %)
Total Effect in %	0.0210 %	0.1024 %	0.0815 %
Resistance Value	100 kΩ resistor	100 kΩ resistor	0
Effect to TCR	100 Ω	250 Ω	150 Ω
Effect of Tolerance	20 Ω	100 Ω	80 Ω
Total Effect	120 Ω	350 Ω	230 Ω

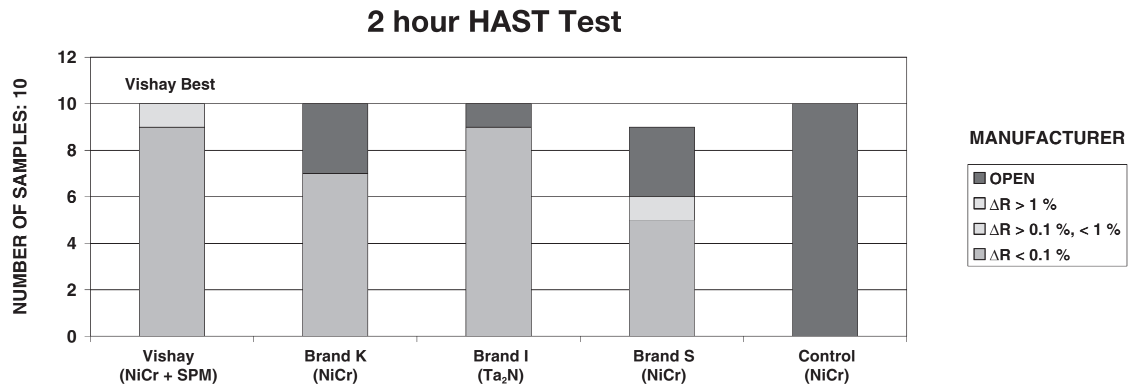
TABLE 4

96 hour HAST Test Summary									
Manufacturer	**Film**	**Coating**	**Size**	**Value**	**Pieces**	**#ΔR < 0.1 %**	**#ΔR > 0.1 %, < 1 %**	**#ΔR > 1 %**	**Open**
Vishay	NiCr	SPM	0805	100K	30	5	24	1	0
Brand 1	Ta_2N	Epoxy	0805	100K	30	5	22	3	0
85/85 Moisture Test Summary									
Manufacturer	**Film**	**Coating**	**Size**	**Value**	**Pieces**	**#ΔR < 0.1 %**	**#ΔR > 0.1 %, < 1 %**	**#ΔR > 1 %**	**Open**
Vishay	NiCr	SPM	0805	100K	30	30	0	0	0
Brand 1	Ta_2N	Epoxy	0805	100K	30	30	0	0	0
Modified MIL Moisture Test Summary									
Manufacturer	**Film**	**Coating**	**Size**	**Value**	**Pieces**	**#ΔR < 0.1 %**	**#ΔR > 0.1 %, < 1 %**	**#ΔR > 1 %**	**Open**
Vishay	NiCr	SPM	0805	100K	30	30	0	0	0
Brand 1	Ta_2N	Epoxy	0805	100K	30	30	0	0	0
56 day Moisture Test Summary									
Manufacturer	**Film**	**Coating**	**Size**	**Value**	**Pieces**	**#ΔR < 0.1 %**	**#ΔR > 0.1 %, < 1 %**	**#ΔR > 1 %**	**Open**
Vishay	NiCr	SPM	0805	100K	30	30	0	0	0
Brand 1	Ta_2N	Epoxy	0805	100K	30	29	0	1	0

Major Advancements in the Protection of Thin Film Nichrome-Based Resistors with Specialized Passivation Methods (SPM)

TABLE 5

2 hour HAST Test Summary								
Manufacturer	**Film**	**Coating**	**Value**	**Samples**	**#ΔR < 0.1 %**	**#ΔR > 0.1 %, < 1 %**	**#ΔR > 1 %**	**Open**
Vishay (NiCr + SPM)	NiCr	SPM	100K	10	9	1	0	0
Brand K (NiCr)	NiCr	Epoxy	100K	10	7	0	0	3
Brand I (Ta_2N)	Ta_2N	Epoxy	100K	10	9	0	0	1
Brand S (NiCr)	NiCr	Ta + Epoxy	100K	10	5	1	0	3
Control (NiCr)	NiCr	Epoxy	100K	10	0	0	0	10



Test Results

To evaluate the SPM samples of high value, small size chip resistors 0805 case size, 100 kΩ, 0.1 % tolerance were selected because of the film density per unit area. Samples of Tantalum Nitride were acquired from the market. In addition to the initial tests ran in Table 4, Vishay also ran the HAST test on 32 different lots over a 10 month period, of Nichrome resistor film of values from 10 Ω to 100 kΩ. No opens or catastrophic failures occurred.

Test Conclusion

The biggest advantage of the HAST test is that it is much shorter test time. The test accelerates activation energies by 50 times or more. Thus a 100 hour test can yield the same results as a 5000 hour 85/85 test. For evaluation of the SPM, the HAST tests is by far the quickest and most severe vehicle. It was determined that after two hours under accelerated moisture pressure cooker testing, most films show signs of failure Table 5).

Data Conclusion

The Vishay Nichrome film utilizing SPM (Special Passivation Methods) coating has the same or better results with all four moisture tests when evaluated against Tantalum Nitride based films. The real question is do these tests simulate the conditions of operation in your application and should you sacrifice the electrical performance advantages of Nichrome in your design? Now with SPM on Nichrome, one has both advantages, superior electrical performance characteristics (better TCR and load-life stability) and no hermeticity problems. SPM has the same moisture performance as Tantalum Nitride.

References

1. JEDEC Standard 22-A110 Test Methods, A110, Highly Accelerated Temperature and Humidity Stress Test (HAST), Electronic Industry Association.
2. MIL Standard 202, Method 106, Moisture Resistance Defence Logistics Agency. Test methods for electronic component parts.
3. *Resistor Theory and Technology*, by Felix Zandman, Paul-Rene Simon, Joseph Szwarc.