Stackpole Electronics, Inc.
Resistive Product Solutions

Technical Article

Precision Thin Film Resistors – Nichrome vs. Tantalum Nitride A Comparison

As more markets and devices add electrical content, the need for precision resistors has increased dramatically. The two main materials for precision chip resistors are nichrome which is an alloy comprised primarily of nickel and chromium, and tantalum nitride. These two materials dominate the precision chip resistor market from a volume and availability standpoint. This article will discuss the similarities and differences between resistors made with these two material types; from manufacturing to material properties, to overall electrical performance as well as where each is more commonly used and why.

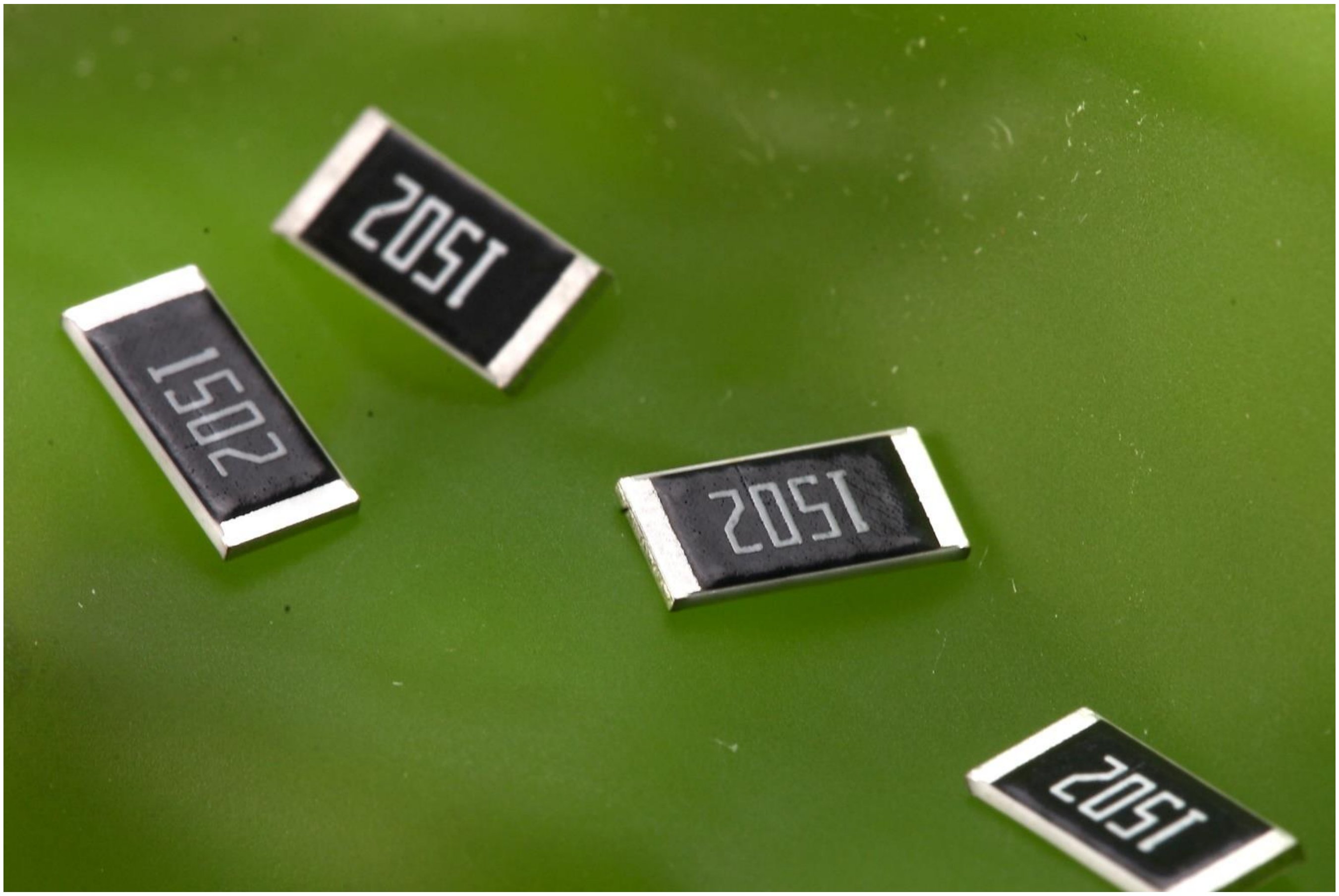
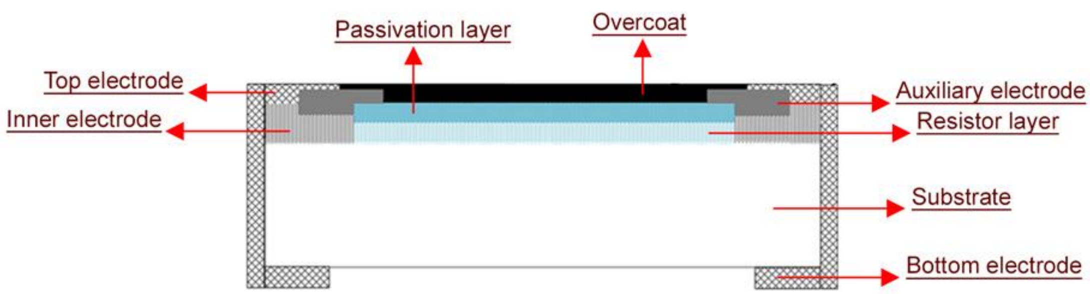


Fig. 1 Precision Chip Resistors

Materials and Processes

Both nichrome and tantalum nitride materials are applied in substrate form using a process called sputtering. Sputtering uses excitation of a noble gas to deposit atoms of nickel and chromium for nichrome resistors or tantalum material for tantalum nitride. The main difference between these two manufacturing processes is that tantalum nitride sputtering requires an inert nitrogen atmosphere as part of the tantalum nitride element formation. Sputtering of nichrome only requires a vacuum, which is much simpler to accomplish in a manufacturing environment. Both materials generally use a photolithography process to define the resistive element. This involves applying a photo sensitive material to the substrate in areas outside the desired element dimensions. Then after deposition of the thin film element, the masked areas are stripped off leaving only the precisely defined element. Both nichrome and tantalum nitride films use laser trimming to calibrate the resistance value to the desired value. A key difference between the technologies lies in the film material characteristics themselves. Sputtered nichrome element film is inherently susceptible to failure by moisture. The effect of moisture intrusion into a sputtered nichrome element is corrosion, also sometimes called oxidation, or dissolution where the resistor itself dissolves and is evaporated. In either case, the resistance value increases and eventually, over time, will cause the resistor to completely open.



Type	Nichrome Thin Film Chip Resistors	Tantalum Nitride Thin Film Chip Resistors
Substrate	Alumina 96%	Alumina 96%
Resistor layer	NiCr	TaN
Passivation layer	Silicon oxide / nitride, or none	Tantalum Pentoxide
Inner electrode	Silver	Silver / Palladium
Auxiliary electrode	Sometimes	Yes

Fig. 2 Construction Cross Section

One key aspect to note of thin film resistor technologies is the passivation layer. A passivation layer is a barrier to moisture that is formed on the top of the element itself and is separate from the epoxy overcoat. Nichrome element resistors may or may not have a passivation layer. Non-passivated nichrome elements will typically fail within 1000 hours under 85°C, 85% relative humidity, 10% rated power biased humidity testing, sometimes within 500 hours for smaller chip sizes. The combination of low bias and high humidity ensures that moisture will not be evaporated due to heat generated on the element itself and is extremely difficult to pass for any surface mount chip resistor, regardless of technology. Non-passivated elements simply have no defense against moisture because the epoxy overcoat cannot be relied upon for moisture blocking. Current techniques for passivating nichrome elements are not trivial. They require significant experience and manufacturing technology; therefore, many manufacturers do not provide passivated nichrome chip resistors. Passivated nichrome elements will typically pass the same biased humidity testing described above with minimal resistance shifts of ±0.1% to ±0.3% depending on chip size as shown in Fig. 3 below. Unfortunately, for applications such as military and aerospace that may need to operate for 30 years or more, eventually these parts may shift beyond a usable tolerance. For those applications, typically tantalum nitride is the only acceptable solution. Tantalum nitride films are self passivating which means any moisture that penetrates the outer overcoat and reaches the element immediately forms a very thin layer of tantalum pentoxide which is impervious to moisture. Where passivated nichrome resistors may shift up to ±0.3% under biased humidity testing, tantalum nitride resistors typically shift less than ±0.05% and many less than 0.01%. Tantalum nitride thin film chip resistors have a proven track record of environmental and electrical stability with some military and aerospace applications utilizing these resistors for many years. However, due to the challenges in the manufacture of tantalum nitride resistors and resulting higher cost, nichrome element thin film chip resistors have a much larger market than those with tantalum nitride. Nichrome thin film resistors are more widely available and are less expensive than tantalum nitride thin film resistors.

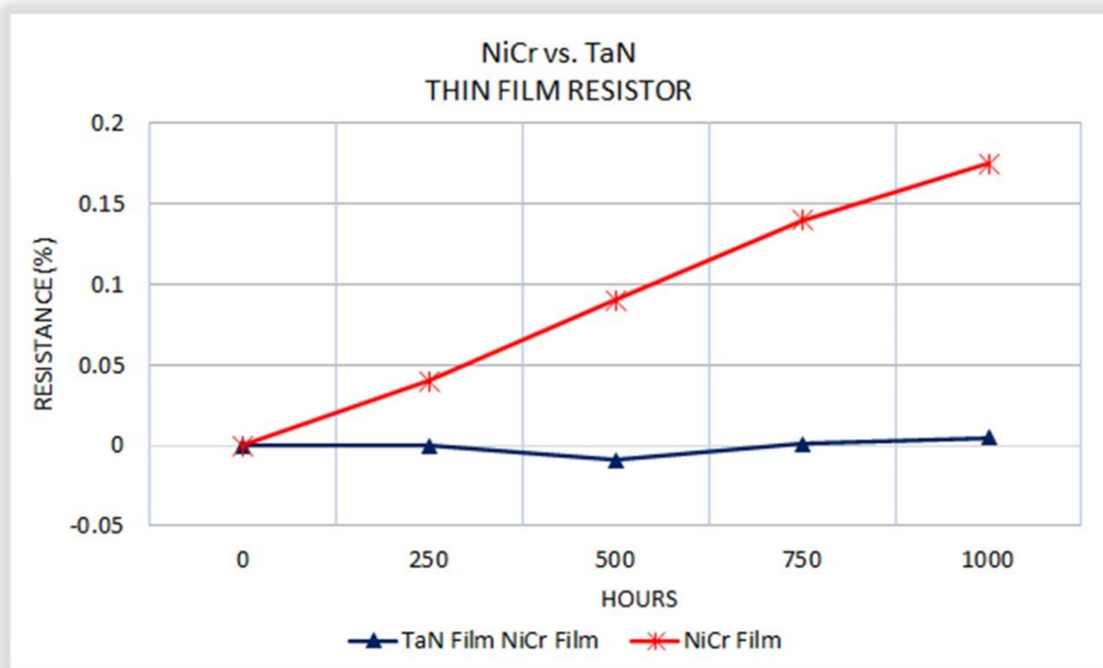


Fig. 3 Biased Humidity Performance Comparison

Electrical Performance

From an electrical standpoint the two technologies both excel at providing precision performance, tight tolerances, low TCR's and good electrical characteristics. However, there are distinct differences between their performances. Nichrome resistor films are superior to tantalum nitride in terms of providing tight tolerances and low TCR's. Where tantalum nitride films typically are capable of 0.1% tolerances and 15 ppm TCR, nichrome thin film chip resistors may be available down to 0.01% tolerances and 2 ppm TCR. The test performance characteristics for nichrome are typically superior to tantalum nitride as well. For most of the key industry standard tests (aside from biased humidity previously discussed), nichrome will typically be twice as stable as tantalum nitride. In addition, nichrome can provide even better long-term stability for the tightest tolerances offered, for some tests and sizes, by an order of magnitude. For applications requiring tight tolerance, low TCR, and stable long term performance, nichrome thin film chip resistors are always the first choice. Medical equipment, patient monitoring, instrumentation, and test equipment are examples of such applications.

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From a pulse withstanding standpoint however, the story changes. Tantalum nitride thin film chip resistors show noticeably higher pulse handling compared to chip resistors with nichrome elements. Both technologies have relatively flat pulse curves, due to the very thin element thickness of each. This is because generally for thin film resistors, shorter duration pulses do not allow for significantly higher pulse handling as is the case for thick film chip resistors. The curves converge as pulse duration becomes longer, which is logical given the similar continuous power ratings for each size regardless of technology used. For longer duration pulses, thin film resistors have superior pulse handling to thick film, due to the significantly higher element density of thin film. However, for pulse durations shorter than around 0.1 sec, thick film resistive elements far exceed the capabilities of thin film for pulse handling because of more element mass. Figure 4 below shows the noticeably better pulse handling for the tantalum nitride element compared to the nichrome element in each chip size.

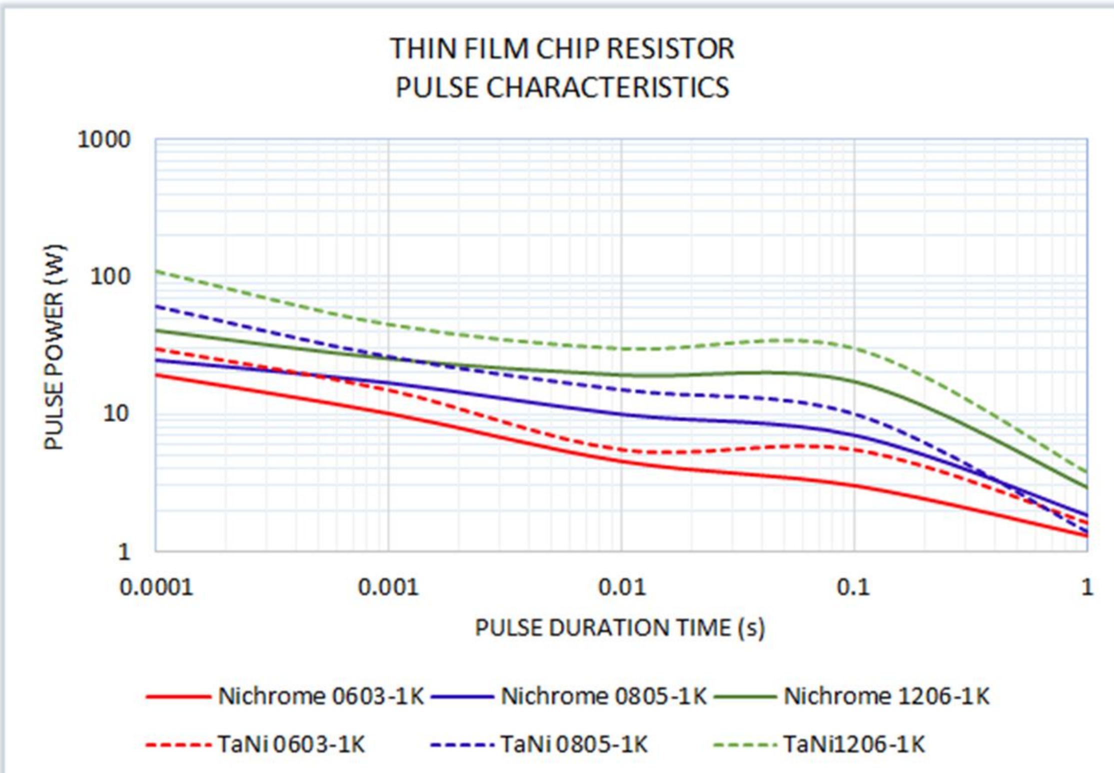

Fig. 4 Pulse Chart Comparison

Summary

The current thin film chip resistor market is dominated by nichrome and tantalum nitride technologies. For applications where precision and electrical performance are critical, nichrome resistors with their ability to provide tight tolerances, low TCR's, and exceptional electrical and environmental performance with competitive pricing are the resistive film type of choice. However, for applications with long term moisture stability requirements or higher pulse requirements, tantalum nitride provides a moisture impervious part with superior pulse handling with far better tolerance and TCR capability compared to thick film precision resistors.

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