WINning with tantalum nitride

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A production process developed by TT Electronics is bringing the high reliability benefits of tantalum nitride for thin film chip resistors to a wider range of applications

There have traditionally been two technologies for making thin-film chip resistors – one reliable but expensive and the other much cheaper but with some quality issues. Now, TT Electronics has turned that on its head by designing a production process that can make the more reliable components at a price that opens up markets that previously would have opted for the lower cost units.

Today, the vast majority of thin-film chip resistors use a sputtered thin film of nichrome for the resistive element. This technology was developed by TT Electronics IRC back in the 1950s and is used widely today. A second method was developed by Bell Labs in the 1960s. This uses tantalum nitride (TaN) with the big advantage that it is not at all susceptible to moisture making it the technology of choice for very high reliability applications.

Nichrome films suffer from the inherent weakness that they break down within seconds when moisture is in contact with the film and a voltage is applied. TaN survives that combination because it produces a stable, protective oxide layer; it is self-passivating. The material in this layer is tantalum pentoxide, which serves as the dielectric in tantalum capacitors, and renders tantalum virtually impervious to chemical corrosion. This is similar to the more familiar behaviour of aluminium, which forms a thin, mechanically stable oxide preventing progressive rusting. However, because of the relatively high cost of the conventional TaN process, it has until now only been deployed in high reliability applications, such as in military and aerospace, high-end computer servers and some critical medical products.

The internal structure of a TaN resistor is shown in figures 1 and 2. These show the typical thin film structure after deposition by sputtering, and after the process of oxide growth. A printed epoxy layer (not shown) is normally added over the resistor element, and this gives mechanical protection and insulation, but is not relied upon for moisture resistance.

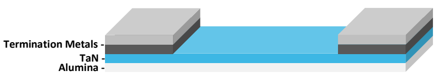

Figure 1. Tantalum Nitride Resistor Structure as Deposited

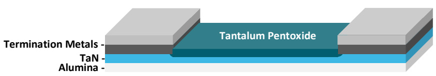

Figure 2. Tantalum Nitride Resistor Structure after Oxide Growth

Nichrome, by contrast, is totally dependent on the way it is protected against the environment. The basic way is to print a layer of epoxy on the top. But no plastic material is

a hundred per cent impervious to water and there can be ingress under the edges. To increase the protection therefore, some manufacturers deposit a thin film of ceramic over the nichrome, below the epoxy layer. This helps but it is still not totally reliable; if the layer is scratched or otherwise damaged, water can still get in.
With TaN, if something disturbs the oxidised layer, it will simply regrow; it is self-healing.

The internal structure of nichrome resistors is shown in figure 3 and that of the passivated version in figure 4. A printed epoxy layer is added over the resistor element, and this is essential for the moisture resistance of the component.

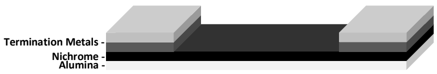

Figure 3. Nichrome Resistor Structure

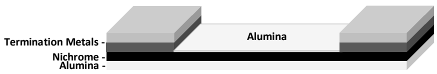

Figure 4. Passivated Nichrome Resistor Structure

Manufacturing process
The main reason TaN has proven too expensive for most applications is that it uses a photo-lithography manufacturing process. A film is deposited on the substrate and is then coated with a photo-sensitive chemical. A mask is then placed on top of that leaving areas that are exposed to ultra-violet light. These areas can then be stripped away. This is a time consuming and costly process.

The new WIN (water insoluble nitride) series of thin-film resistors changes that process to one using laser patterning. This is a far simpler process with the added large advantage that the deposition or front-end process can be done in advance creating a small number of standard substrates. Each block covers a broad range of finished values. When an order is received, the back-end process can be carried out to complete the order. This reduces lead times compared with photo-lithography where the whole the process has to be done from scratch every time an order is received.

Using laser scribing with automatic snapping equipment has achieved further cost and time savings compared with the diamond wheel dicing method used previously. Other manual processes have been replaced with automated equipment with improved process controls, sensors and computer monitoring. These have increased yields and reduced restarts.
The company has also reduced material costs due to the design of the terminations. The use of precious metals has been eliminated apart from in a small, targeted area where it improves the termination integrity.

Benchmark testing
In order to test the comparative moisture resistance of WIN TaN film against nichrome and its passivated variant, a pressure cooker test was used. This highly accelerated life test method exposes components to saturated water vapour at a high pressure of 15psi at 120°C. The results, shown in figure 5, indicate that commodity nichrome types all fail after 10 hours of exposure. The addition of alumina passivation gives a measureable benefit, with 20 to 50% of passivated nichrome parts still operational after 10 hours. But only WIN

TaN film delivers a 100% survival rate under these challenging conditions, demonstrating a clear advantage over passivated nichrome resistors.

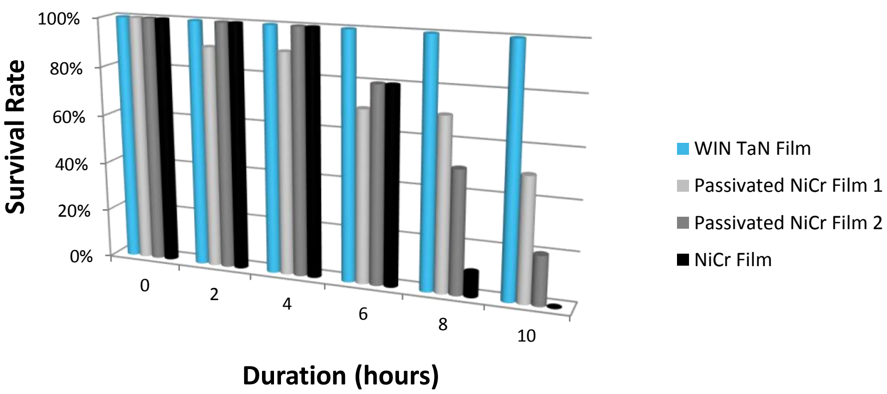

Figure 5. Benchmark Accelerated Life Test (Pressure Cooker Test 15 psi, 100%RH, 120°C, 10 hours)

The tantalum issue

Many engineers will be more familiar with tantalum in the field of capacitors. Here, the material has been known for unstable supply problems, leading at times to shortages and sharp price variations.

However, TaN resistors use so little tantalum that this is simply not an issue. A typical tantalum capacitor has tens of milligrams of tantalum. A TaN chip resistor, on the other hand, has just a few micrograms, in other words a 10,000:1 ratio. Sensitivity to variations in tantalum price levels is therefore correspondingly negligible.

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Future developments

The WIN series resistors are the first products using this process. They are available in 0603, 0805 and 1206 sizes at 0.1, 0.25 and 033W, respectively with resistance values from 10R to 1M0. Future planned developments will bring a high temperature version and improve the precision from WIN's tolerance of ±0.1% and TCR of ±25ppm/˚C.