Behavior of thick film technology at high temperatures

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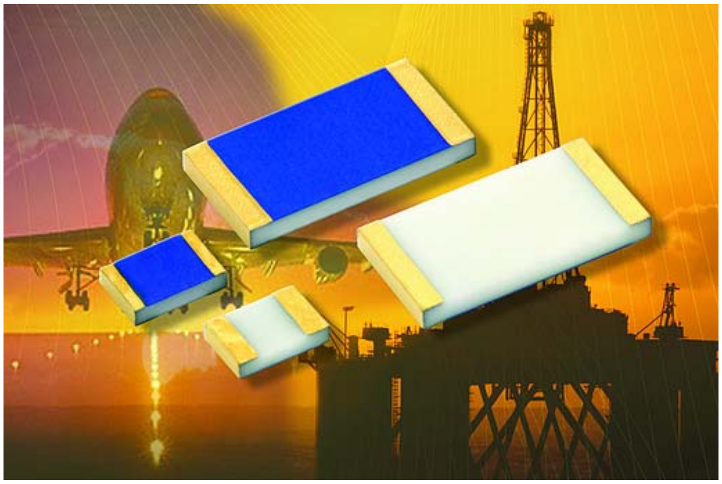

A new thin film technology was tested to address design engineers' demand to increase the operating temperature range up to 250°C with load, which means a junction temperature at the resistive layer level of 270°C.

The thick film resistive ink often used to produce thick film devices is calibrated with conductive ink to guarantee the best load-life stability. This stability, combined with the treatment parameters for the inks, allows the qualification of thick film technology at temperatures up to 230°C with load, and at 245°C without load. This is well beyond the capabilities of the standard ruthenium oxide ink available on the market. To create components that withstand such temperatures, specific processes and materials must be used.

To be effective, components need to be mounted onto an appropriate PCB to withstand extreme temperatures for an extended time. During some testing scenarios undertaken by Vishay Sfernice, load-life stability was in some cases halted due to break-out of the PCB, although the thick film chip resistor itself did not drift drastically with load life.

To determine load-life stability, testing on different lots (with different resistivity) showed similar behavior after 1000 hours. Extended testing was then performed for 4000 hours on a lot of high-temperature thick film chip resistors.

Parts were mounted onto polyimide (standard copper coverage) with a HMP process (93.5% Pb, 5% Sn, 1.5% Ag). Load life after 500 hours was controlled. The PCB broke down after 500 hours.

A temperature coefficient test was done to compare the behavior of standard thick film chip resistors over a temperature range of -55° to +155°C with the high-temperature thick film chip resistor having the same resistive layer, gold terminations, and built on the same process over the temperature range of -55° to +200°C.

Measurements of various lots featuring different resistivity characteristics showed:

- Behavior for high-temperature chip resistors in the temperature range of -55° to +200°C is the same as standard thick film chip resistors in the temperature range of -55° to +155°C;
- Consistency of measurement, whichever resistivity is used; and
- Based on the various tests, it can be estimated that the temperature coefficient will remain within the 100 ppm/°C range at temperatures up to 230°C.

Previous work has shown that the performance of a high-temperature thin film chip resistor is a function of the process under which the devices are manufactured. Experimental data have shown load-life stability for a high-temperature thin film chip resistor of 0.35% after 2000 hours at 220°C and nominal power.

A new test was performed to confirm the behavior of high-precision, high-temperature chip arrays. Measurements were performed at 70°C on different lots with different resistivity characteristics for more than 2000 hours at different periods of time.

The test results showed consistent behavior for standard chip arrays with an average load-life drift on ratio of 0.05% after 2000 hours.

Measurement of the high-temperature thin film chip array was performed at 230°C on two different lots with two different resistivity characteristics over more than 8000 hours. The test results showed typical drift on the ratio around 0.15% after 8000 hours. The parts stabilized after 2000 hours.

From the above testing it could be concluded that:

- The use of a high-temperature chip array allows for an improvement of load-life stability by almost a third, with an average of 0.15% vs. 0.35% for a discrete high-temperature chip resistor, after 8,000 hours, and
- The manufacturing process has a direct impact on the behavior of the parts, but load-life drift is consistent regardless of resistivity characteristics.

While previous work done by Vishay presented long-term stability data after 8000 hours of testing, it has carried out more testing and now have figures for data after 20,000 hours.

Some PCBs were broken (at 215°C and 230°C), so measurements were stopped. It was interesting to note the drift due to temperature from one curve to the other. All stabilized for the first time after 1000 hours and for a second time after 10,000 hours.

So, as previously presented, by controlling the junction temperature at the resistive layer level, one can minimize the load-life drift of the parts.

The question manufacturers need to answer for design engineers is to what extent the power rating affects drift over time. Vishay performed comparison tests with and without loads, at 220°C and 230°C, to check how the load could affect performance and to provide design engineers with a rule to estimate the load-life drift at a given temperature from the 20,000-hour stability curve without a load.

There is more and more the demand to increase the operating temperature range up to 250°C with load, which means a junction temperature at the resistive layer level of 270°C. A new thin film technology was tested with this objective in mind.

More testing will be needed to confirm the behavior of this new thin film, but test results are already very promising and show consistent performance from lot to lot and regardless of resistivity.

The measured TCR of 10 ppm/°C maximum in the -55° to +250°C operating range might still be worked upon and limited in the future to 5 ppm/°C.

All these high-temperature chip resistors and resistors arrays are given at a rated power at 220°C or 250°C, but design engineers might need to know the admissible power at temperatures between 125°C (the highest standard temperature for electronic components) and 250°C. A new presentation of the "uprating/derating curve" provides this.

On the curve, 100% of the nominal power is reached at 215°C. There is a derating between 215°C and 230°C from 100% of nominal power and 0%. On the other hand, there is an “uprating” power between 215°C and 70°C. At 70°C, the part can withstand 330% of nominal power. For example, a 1206 chip resistor will withstand 100 mW at 215°C and 50 mW at 220°C, but will withstand 330 mW at 70°C and 200 mW at 170°C.

The same curve is available for very high-temperature thin film chip resistors, where 100% of the power rating is reached at 250 °C. For example, a 1206 chip resistor will withstand 165 mW at 250°C and 330 mW at 150°C, but only 82 mW at 260°C.

From an analysis of the various load-life stability curves, it has been shown that the features of the thin film or thick film layers used, as well as the type and thickness of the termination, are a guarantee of good behavior in high- or very-high-temperature operations.

Design engineers have been provided with tools to allow them to estimate load-life drift after 20,000 hours based on the junction temperature and long-term stability curves, as well as an uprating/derating curve that can be used ton calculate the maximum admissible power rating at any given temperature between 125°C and 250°C.

It has been demonstrated that the use of resistor chip arrays significantly reduces the drift on the ratio compared to absolute drift of discrete chip resistors by at least a factor of 2.

The next step is to look for appropriate supports and a heatsink able to withstand temperatures up to 270°C/285°C on a long-term basis.

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