ESR Stabilization of Ta Capacitors for Automotive Applications in Severe Environmental Conditions

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Abstract

Present day state-of-the-art automotive electronics require Tantalum chip capacitors not only with reduced ESR levels but also with increased ESR stability against harsh environmental conditions. With this purpose, a novel process step was used in the production of several tantalum types designed for automotive applications, spanning a range of low and high voltages.

In-line electrical behaviour of treated parts showed no significant modification relative to conventionally produced ones, albeit a small increase in the average ESR level. For demanding temperature and humidity environments, reliability testing data showed a significant improvement of overall ESR stability without deterioration of DC leakage behaviour, in particular for high voltage types. These results show the new process to be a promising technique towards achieving highly reliable high voltage automotive Tantalum chip capacitors.

Introduction

Automotive Electronics OEM's currently request for sophisticated application modules that Ta-chip capacitors are able to meet stringent ESR stability requirements. Not only is it required that a given maximum ESR level at room temperature is fulfilled, but also that the component ESR must be inside a "window", defined for a range of temperatures, while maintaining the reliability levels expected of an automotive grade component.

This kind of requisites poses new challenges for tantalum chip capacitor manufacturers, concerning ESR stability under stressful environmental conditions. With the objective of addressing these issues, a novel process step was developed [1].

A tantalum chip capacitor is produced from a pellet made out of pressed Ta powder, with an embedded Ta wire, which is then sintered (anode). By anodic oxidation a dielectric layer of Ta_2O_5 is grown on the pellet surface. The cathodic layer is composed of MnO_2 and is obtained in a sequence of steps of $Mn(NO_3)_2$ impregnation and pyrolysis. Graphite and Silver (the *contact layers*) are then deposited in order to assure a good electrical contact with the leadframe. Finally the capacitor is encapsulated in an epoxy resin. The new process step in study in the present work is used in the contact layers deposition phase.

The feasibility of using this new process step in the production of Ta-chips designed for automotive applications is evaluated in this study. Its impact in the electrical parameters of finished capacitors is analysed and environmental tests are conducted in order to assess the reliability of the produced parts under harsh temperature and humidity conditions.

Experimental

Five different types designed for automotive applications were tested: 6.3V chip B, 10V chip D and 35V chips A, C and D. These were chosen in order to cover small to large case sizes at low and high voltages. Sets of these capacitors were produced using the new process step and, in parallel, the standard process sequence, in order to allow a direct comparison between both conditions. In Table I the design data of the several tested types is presented:

Case size	Application voltage [V]	Ta-powder CV [uC/g]	Formation voltage [V]
A	35	10k	140
B	6.3	80k	30
C	35	20k	135
D	10	40k	35
D	35	10k	140

Table I – Design data of tested types.

Electrical parameters of the finished capacitors were measured with Hewlett-Packard 4263B LCR and 6634-B DC power supply meters.

All parts were subjected to Endurance 125C (125ºC / 0.67 x Rated voltage / 1000h) and Biased Humidity (85ºC / 85% Relative Humidity / Rated Voltage / 1000h) life tests. Due to the stressful environmental conditions these impose on tested samples, they are widely used to access the reliability of parts designed for automotive applications. The tests were performed on groups of 77 capacitors of each part type, for all production conditions.

Results and Discussion

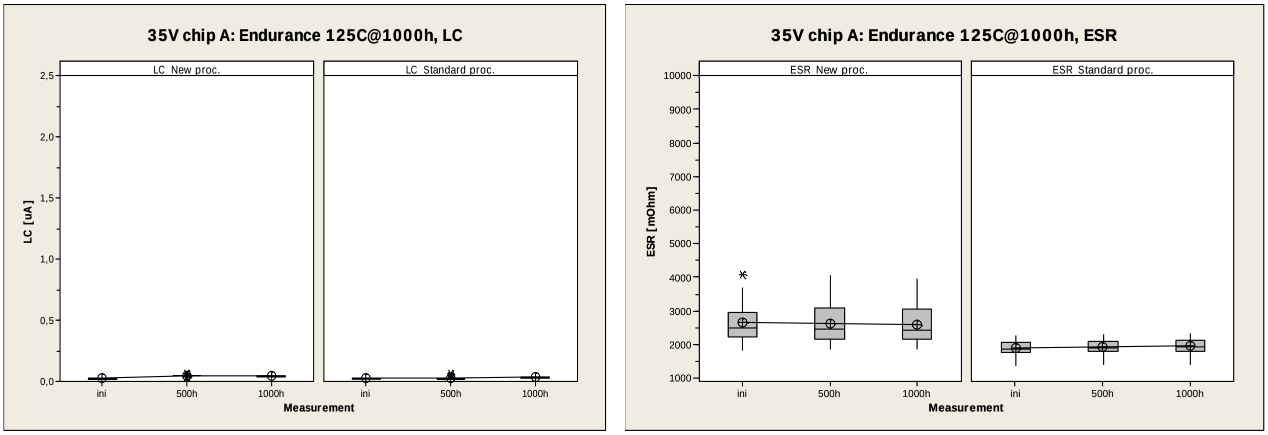
A comparison between end-of-line electrical results of parts produced with the standard process and those of parts produced using the new process step, for each of the studied types, is presented in Table II below:

	Type									
	A / 35V		**B / 6.3V**		**C / 35V**		**D / 10V**		**D / 35V**	
	Standard process	***New process***	***Standard process***	***New process***	***Standard process***	***New process***	***Standard process***	***New process***	***Standard process***	***New process***
LC avg [uA]	0.027	0.031	0.201	0.276	0.165	0.159	0.666	0.573	0.295	0.248
ESR avg [Ohm]	1.250	1.530	0.210	0.320	0.300	0.410	0.062	0.059	0.210	0.310

Table II - End-of-line LC and ESR measurements.

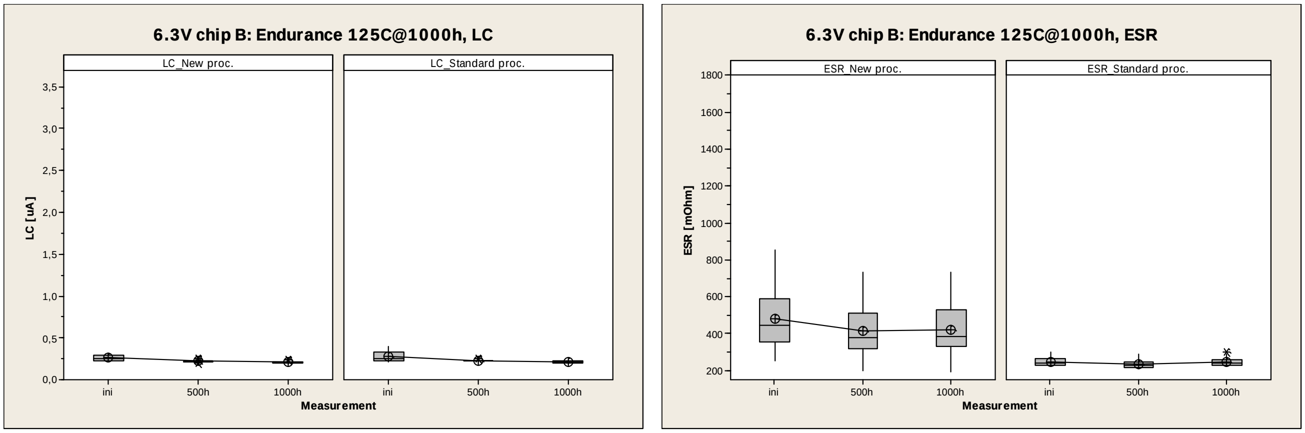
It can be seen that, in general, the ESR level is slightly higher for parts produced using the new process step than for parts produced using the standard sequence. Only in the case of the 10V chip D there was no significant modification of the ESR level between both production conditions. The new process step doesn't impact significantly the LC level in any of the cases.

After completion of the production cycle the parts were subject to environmental testing, as described above. The results of the Endurance 125C test are presented in the graphs of Figs. 1 to 5. Biased Humidity test results are presented in Figs. 6 to 10.



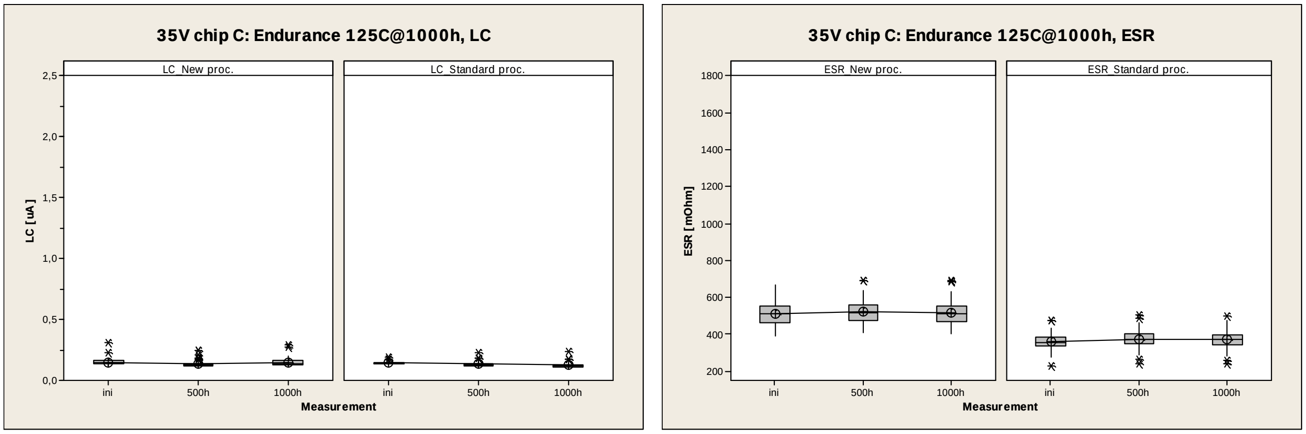
(a) (b)

Fig. 1 – Endurance 125C life test data for 35V chip A: a) LC; b) ESR.



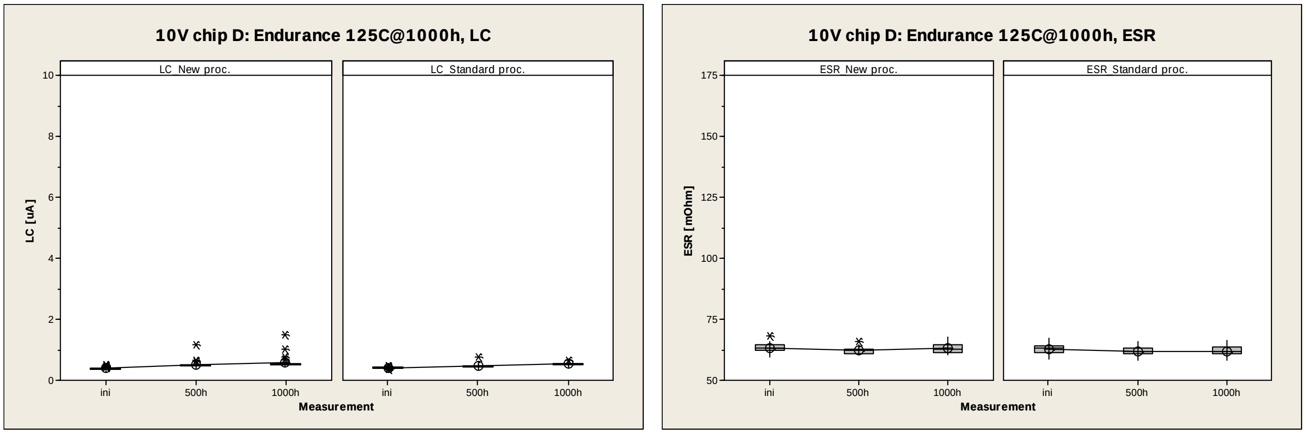
(a) (b)

Fig. 2 – Endurance 125C life test data for 6.3V chip B: a) LC; b) ESR.



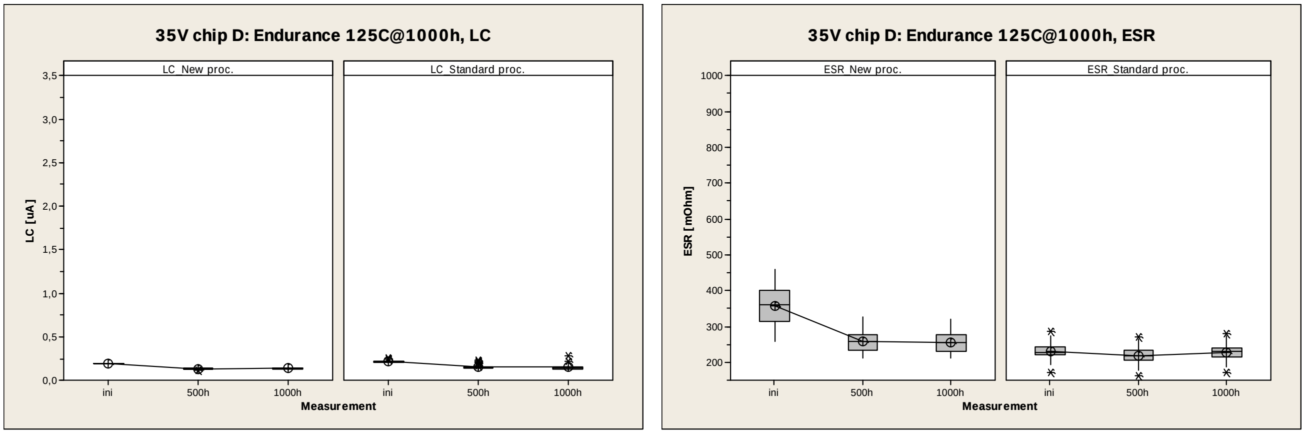
(a) (b)

Fig. 3 – Endurance 125C life test data for 35V chip C: a) LC; b) ESR.



(a) (b)

Fig. 4 – Endurance 125C life test data for 10V chip D: a) LC; b) ESR.

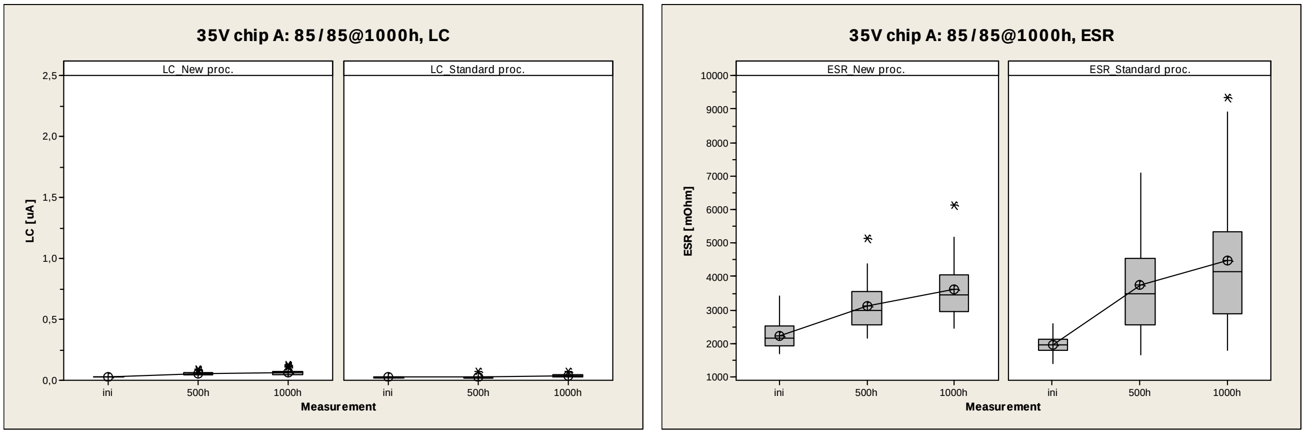


(a) (b)

Fig. 5 – Endurance 125C life test data for 35V chip D: a) LC; b) ESR.

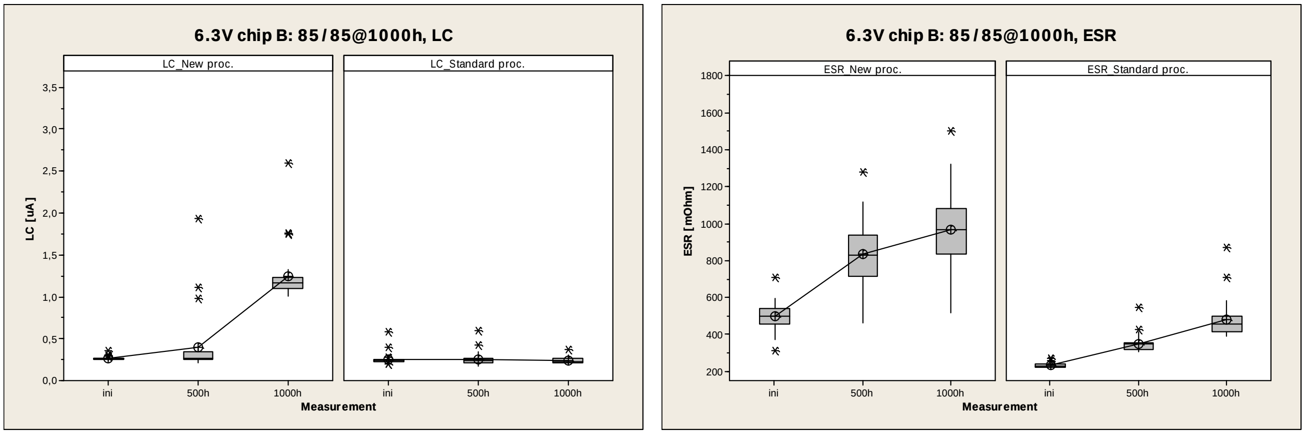
In general, the LC results after 1000h at 125ºC are similar between parts with and without the new process step. The parts present a relatively stable LC behaviour. In the case of the 10V chip D the parts produced with the new process step show slight drifts from 500h to 1000h, but these should not be considered significant.

Regarding the ESR results, it can be seen that the new process produced parts present higher ESR levels when compared to standard parts, with broader distributions, but show stable behaviour even after 1000h.



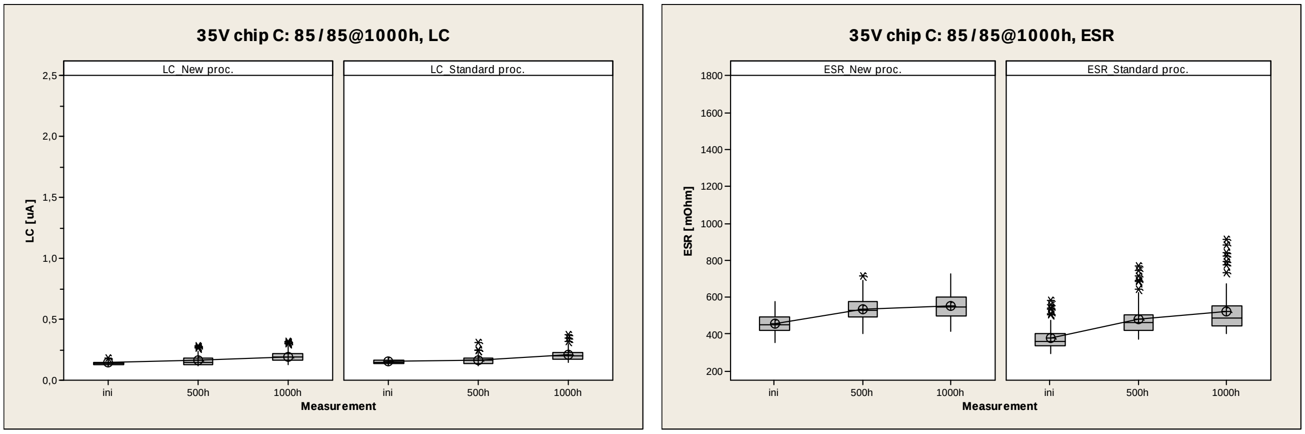
(a) (b)

Fig. 6 – Biased Humidity life test data for 35V chip A: a) LC; b) ESR.



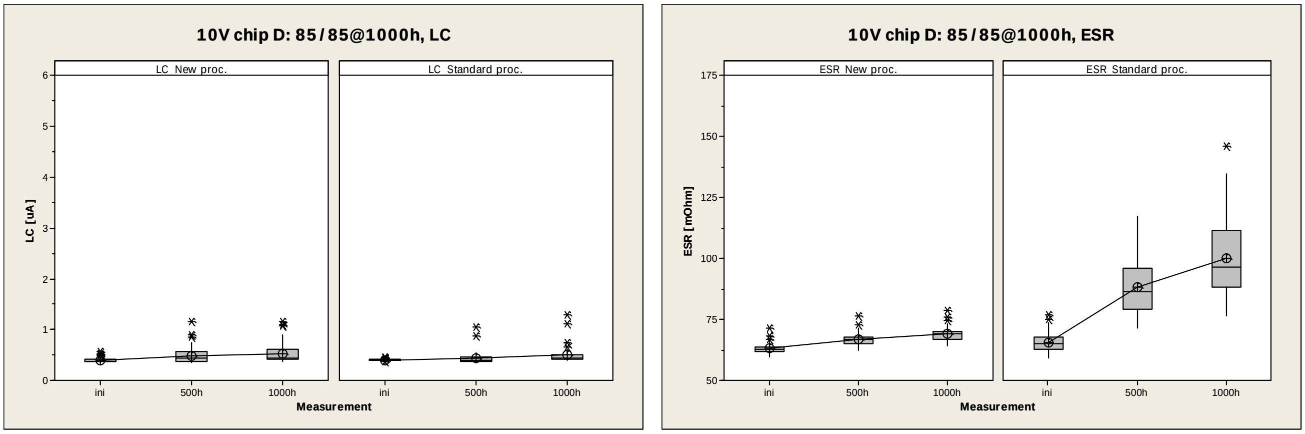
(a) (b)

Fig. 7 – Biased Humidity life test data for 6.3V chip B: a) LC; b) ESR.



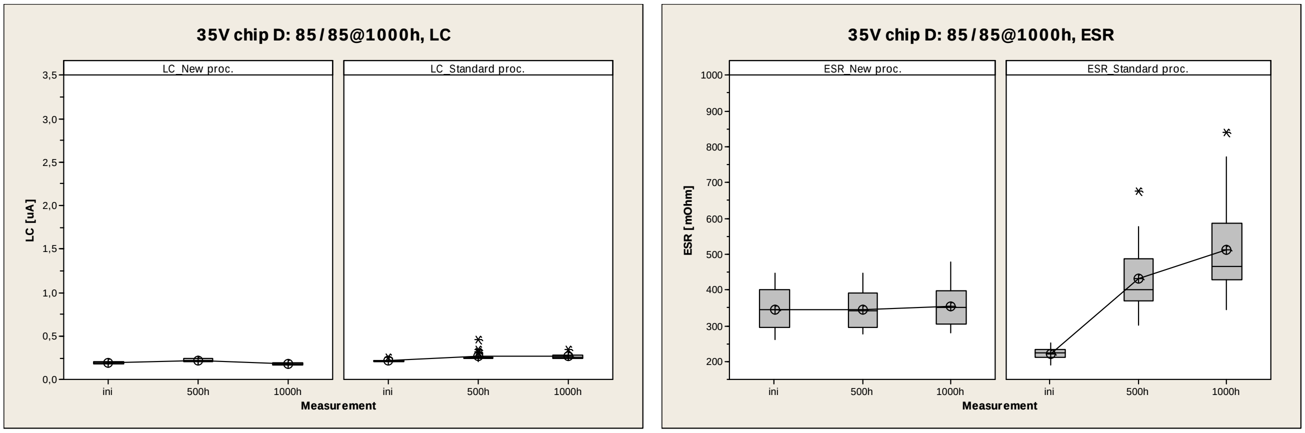
(a) (b)

Fig. 8 – Biased Humidity life test data for 35V chip C: a) LC; b) ESR.



(a) (b)

Fig. 9 – Biased Humidity life test data for 10V chip D: a) LC; b) ESR.



(a) (b)

Fig. 10 – Biased Humidity life test data for 35V chip D: a) LC; b) ESR.

Biased Humidity LC behaviour is similarly good for parts with standard and new process sequences in all cases, except for the 6.3V chip B, in which the parts with the new process step show a clearly worse result. The parts are unstable, with drifts that increase during the course of the test.

ESR behaviour in the cases of the 10V chip D and of the 35V chips A and D shows to be more stable, *i.e.* with lower or no drift, for parts that use the new production sequence in comparison with those produced with the standard one. In the case of the 35V chip C, although the overall distribution drifts are identical for both types of parts, there is a considerable number of outliers in the standard process distribution that present increasingly larger drifts during the course of the test, ending up with the highest ESR levels after 1000h. Therefore, in this case one can consider also a positive impact of the new process step on ESR behaviour.

In opposition to the other tested types, the 6.3V chip B shows larger ESR drifts, with higher average levels and broader distributions in the parts processed with the new sequence. There is no clear explanation that justifies the negative impact of the new processing condition on the overall Biased Humidity behaviour of this type. However, one possibility may lie in the fact that, from all the tested types, it is the only one designed with a high CV Ta-powder (80k uC/g). Further investigation is needed to verify this hypothesis.

From the whole of the above it can be stated that implementation of the new process step does not have a significant impact in the behaviour of the parts subject to the Endurance 125C test. However, in what concerns Biased Humidity testing there is a clear benefit regarding ESR stability without compromise of LC behaviour, especially in the case of high voltage types.

Conclusions

The impact of a novel process step used in the production of automotive Ta types in their in-line and reliability testing behaviour was studied.

It was shown that in-line electrical performance is only minimally affected, the only noticeable effect being a small raise in the mean ESR level.

It was demonstrated that under Biased Humidity testing conditions there is a major improvement of ESR stability without degradation of LC performance, these being particularly significant in the case of high voltage application types.

In summary, this novel process step shows promising results for the production of highly reliable Tantalum chip capacitors, capable of operating under stressful environmental conditions, as is in general the case of high voltage automotive applications.

Ackowledgements

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References

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