Extension of the space qualified MLCC's ranges

Dr. Henri Laville[1]
Maud Fabre[1]

[1] Exxelia – Capacitors GBU
Z.A.E. du Clos du Chêne – 1, rue des temps modernes
F-77600 CHANTELOUP en Brie – France
henri.laville@exxelia.com

INTRODUCTION

Miniaturization is a driving need for space applications. This need gives rise to the Surface Mounting Devices trend which allows to manufacture more and more compact equipment which at last are cheaper to produce and put on orbit.

But this evolution, which is true whatever the application is, implies some modifications in the manufacturing process of the ceramic chips capacitors and in the based material used to manufacture them. Two options have been considered by Exxelia to enable multilayer ceramic capacitors to withstand these new constraints:

- To design smaller capacitors (down to size 0402) and lowest rated capacitors (down to 10V), what means a complete work on the design rules and the manufacturing process of these products. The main challenge consists in reducing the dielectric thickness considered to manufacture the parts and to guarantee in the same way a sufficient reliability of these thin layers.
- To design alternative components with reduced losses in order to minimize heating. As losses are mainly due to the ceramic dissipation factor, such a choice implies a complete change of the ceramic dielectric. This second possibility lead up Exxelia Technologies to evaluate a new ceramic capacitors range based on a new dielectric material called C48X.

QUALIFICATION OF THE SIZE 0402 AND OF THE 10V RANGE

Technical Constraints

As a reminder, Exxelia already introduced in the QPL a full range of ceramic chips capacitors, from sizes 0603 to 2220, from 16V to 100V.

Exxelia went further and decided to qualify the size 0402 and the 10V range.

The qualification of these two new ranges has implied :

- To work on the design rules of the capacitors and in particular on the reduction of the dielectric thickness.
- To work on the manufacturing process in order to guarantee the reliability of these thin ceramic layers.
- To develop new equipments for the metallization (Figure 1) and the control of these very small capacitors.

Figure 1 : New metallization equipment

Accessible ranges

Different configurations of terminations have been considered for this qualification:

- Ag/Pd/Pt termination
- Nickel barrier + Sn/Pb 60/40
- Nickel barrier + Gold
- Polymer + nickel barrier + Sn/Pb 60/40 or Gold : This polymer termination includes a soft layer which acts as a "stresses buffer" and prevent the chips cracking (Figure 2).

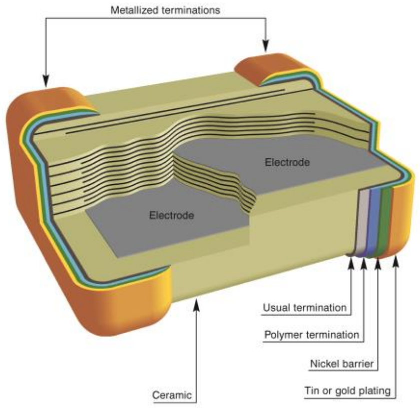


Figure 2 : Flexible termination drawing

Qualification program

The qualification tests have been performed with the help of the French space agency (CNES) and are described in the generic specification ESCC n°3009 (Figure 3).

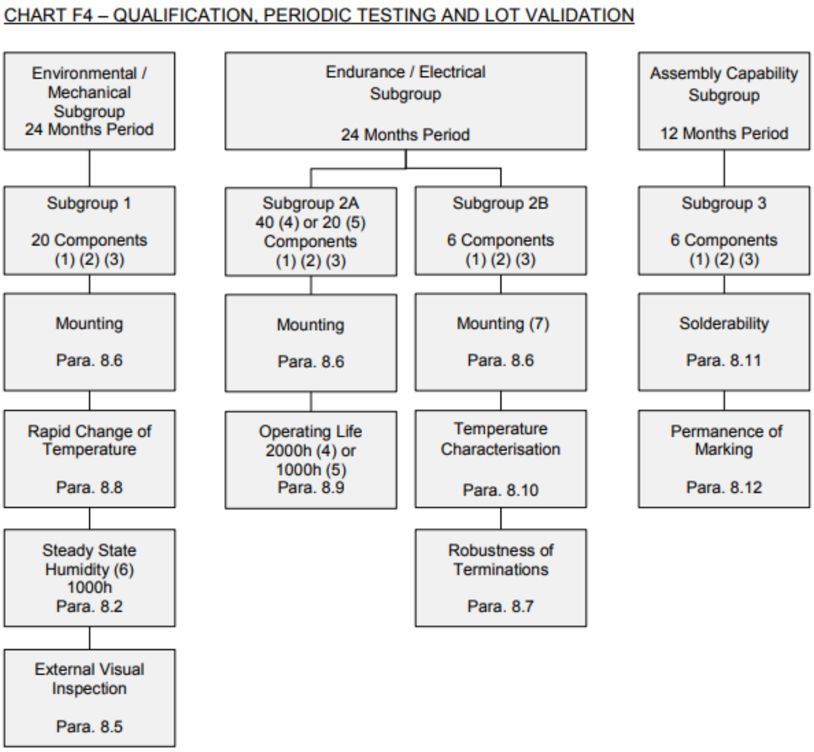


Figure 3 : Description of the qualification tests performed

The qualified ranges are detailed in the Figure 4.

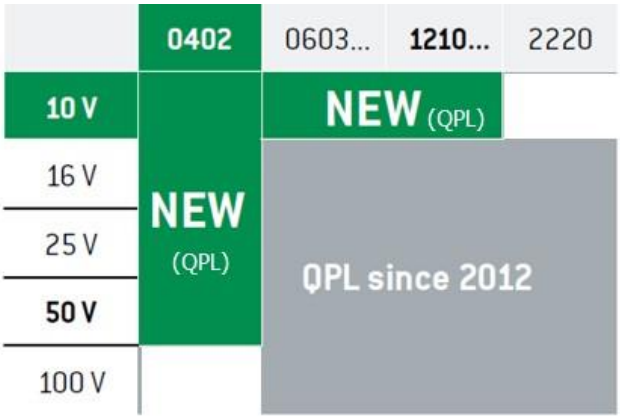


Figure 4 : New qualified ranges

EVALUATION OF THE NEW C48X CERAMIC

Technical Constraints

Two classes of dielectric are mainly used to manufacture ceramic capacitors. The first class is mainly composed of NPO ceramics. These ceramics are mainly made of titanium dioxide with a low dielectric constant ($\varepsilon_r \leq 100$). These ceramics are very stable with only minor changes under stresses of temperature, voltage and frequency.

The second class is composed of X7R ceramics. These ceramics are mainly made of barium titanate with perovskite structure and have a high dielectric constant ($1000 \leq \varepsilon_r \leq 5000$). The counterpart is that these ceramics present some noticeable variations under temperature, voltage and frequency

With the aim of changing the dielectric material used to manufacture Exxelia high voltage ceramic capacitors, what was Exxelia's first goal, it was obviously necessary to use a ceramic whose performances would allow to:

- Develop ranges with the same capacitance / voltage / volume characteristics than the X7R dielectrics
- Dissipate less energy than X7R materials, what means selecting a dielectric with a dissipation factor much lower than X7R's dissipation factor –which is typically for high voltage parts equal or greater than $50 \cdot 10^{-4}$.

Our choice has been a dielectric with an intermediate dielectric constant value (about 450). This material can be processed using a greater voltage gradient (ratio of voltage and dielectric thickness) than X7R dielectrics so that its capacitance per volume could be comparable with the capacitance per volume of an X7R material.

Dielectric Performances

The main characteristics of the selected material which combines most of the advantages of NPO and X7R materials are summarized in Table 1.

Table 1 : Main characteristics of "C48X" material

Dissipation factor at 1kHz, $1V_{eff}$:	$\leq 10 \cdot 10^{-4}$
Typical DF at 400Hz, $1V_{eff}$:	$\leq 5 \cdot 10^{-4}$

Insulation resistance at 20°C under 500V_{cc} :	≥ 20 000MΩ or 500MΩ·µF
Dielectric withstanding voltage :	>1.4 U_{RC}
Temperature coefficient :	-2200 ± 500 ppm/°C

The dielectric constant of this ceramic, smaller than the dielectric constant of classical X7R materials, enables to manufacture about half the capacitance of X7R ranges when measured under standardized measurement conditions (Figure 5), what, at a first glance, appears, of course, to be a limitation.

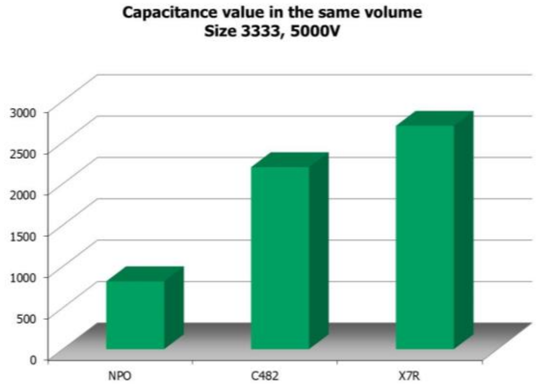


Figure 5 : Comparison of capacitance ranges in the same size package for NPO, C48X and X7R

But this dielectric is very stable under voltage. The loss of capacitance versus dc voltage is only a couple of % (Figure 6) when it's about 60% or more for classical X7R (2R1) ranges.

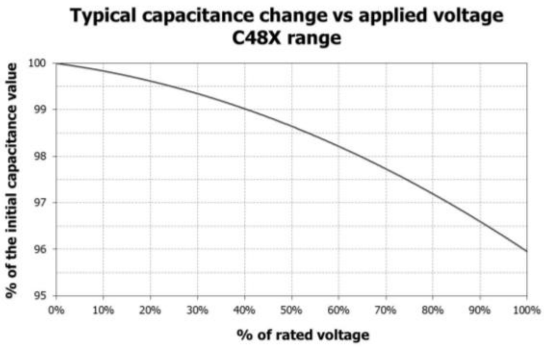


Figure 6 : capacitance change of C48 versus dc voltage

So, when looking at the capacitance value left under nominal voltage (working voltage), a simple calculation demonstrates it's the same when using this ceramic and when using a X7R ceramic dielectric.

Furthermore the dissipation factor is very low, typically less than 0.05% what makes the heat dissipation in use not significant.

Under working conditions the capacitance values of this new range of products are equivalent to X7R values with the unrivaled advantage of no heat dissipation. Opposite to X7R, the C48X capacitors don't suffer a temperature increase, what makes them more reliable.

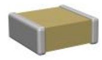
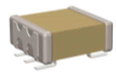
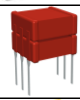
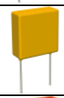
Accessible ranges

Because of its much lower DF, this ceramic is also much better adapted to low frequencies applications (typically 50Hz and 400Hz) than the X7R materials. That's why it's by now for example widely used in plane electrical network in medium or high voltages applications (typically between 400V and 5kV). As already stated our 1st goal was to evaluate high voltage ranges (chips sizes from 1812 to 6560 – voltages from 200V to 5kV) according to space requirements in order to promote a "no heat dissipating" alternative to X7R high voltage parts.

But, in a second step, it appeared obvious that except for impedance matching applications, this dielectric, because of its much higher dielectric constant compared to NPO materials, could be proposed to develop small sizes (0603 to 1210) low/medium voltages ranges (100V to 1kV). The big interest of this choice is that it will allow to propose for a given volume parts with higher capacitance (expected ratio about 3 to 4) and, hence, contribute to equipment miniaturization.

Many mounting possibilities are offered. Some are compatible with through-hole insertion whereas other are fitted for surface mounting. Table 2 herebelow presents most of these options.

Table 2 : Summary of the different configurations proposed for the C48X ranges

Type	**Leads / Finishing**	
Chip	Ag/Pd/Pt, Sn, Sn/Pb, Au Polymer version available	
DIL & Ribbons (chips and stacked capacitors)	DIL connections for surface mounting	
	Ribbon leads / varnished	
	DIL connections for through-hole mounting / varnished	
Through-hole connections	Tinned copper / dipped	
	Tinned copper / molded	

Evaluation program

This work has been done with the help of the french space agency (CNES) and is based on the classical ESCC2263000 evaluation program completed by several additional investigations which can be summarized as follows:

- Thermal shocks (up to 100) have been performed on mounted components. After completion of the thermal shocks a 85/85/1,5V steady state humidity test has also been performed on the same parts.
- Vibrations and shocks according to ESCC3001/3009 recommendations
- A thermal shocks (-55°C,+125°C) test, 500 cycles
- Corona testing according to Appendix B of MIL-PRF-49467C
- Heating of the components working under ac current (done in parallel with X7R capacitors of same capacitance and rated voltage)

The evaluated ranges are detailed herebelow.

High Voltage (200V to 5000V)

- SMD chips with flexible termination, sizes 1812 to 4040
- DIL connections for surface mounting , sizes 2220 to 6560
- Dipped and molded radial leaded capacitors chips size from 1812 to 6560

Low/Medium Voltage Small Sizes(100V to 1000V)

- SMD chips sizes 0603 to 1210

All the tests have been performed successfully and the introduction in the EPPL is planned in S3 2018.

CONCLUSION

The on-going evaluation and qualifications of ranges based on C48X material have been performed in order to answer to the increasing need of miniaturization of our customers.
The results obtained are fully compliant with our expectations and will enable to complete our existing space offer.
In addition, Exxelia pursues his efforts and continues to propose new ranges for next qualifications, with the help of CNES.