Introduction of Small Size MLCC to Aero-Space Application and its technology

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ABSTRACT

Murata has developed a Small High-capacity multi-layer ceramic capacitors for space application using a thin layer technology, previously used for consumer, then for automotive applications.

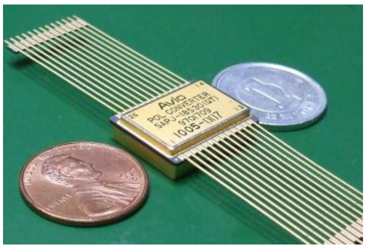
Currently five items are available from 0.1μF to 22μF which were qualified by up-screening from automotive version.

In order to realize a small size and high capacity Multi-layer ceramic capacitor, Murata used thin ceramic sheet technology, uniform and refined inner electrode(Ni) technology, and control technology of the oxygen vacancies.

In this paper, I will introduce the technology with product introduction of Small Size High capacity multilayer ceramic capacitor.

1.Introduction

Murata has received a development request for small size high-capacity products from Nippon Avionics and JAXA to POL (Point Of Load) DCDC converter.(Fig.1)



High Capacitance MLCC

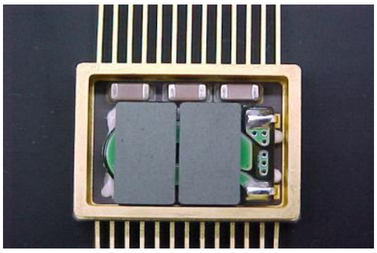


Fig.1 Out sight　　Inner sight

Because of the thin dielectric thickness test conditions and acceleration factors had to be analyzed and verified. The dielectric thickness of the ceramic was reduced to 3 micrometer. Finally 5 Items received JAXA certification in June of 2012 as JAXA-QTS-2040/M105 (Table 1), which were developed for POL DC/DC converter, assured for S-level.

Table 1　JAXA-QTS-2040/M105 Item

Photo.	Part No.	Ratio voltage (V)	Capacitance (uF)	Nominal Dimension L×W×T (mm)	Dielectric thickness (um)	Mass (mg) (Typical)
①	J2040/M105-1608X7RC104	25	0.1	1.6×0.8×0.8 0603 inch	9	7
①	J2040/M105-1608X7RB105	8	1.0	1.6×0.8×0.8 0603 inch	3	7
②	J2040/M105-3216X7RB106	8	10	3.2×1.6×1.6 1206 inch	3	55
②	J2040/M105-3216X7RA226	3.5	22	3.2×1.6×1.6 1206 inch	3	55
③	J2040/M105-3225X7RB226	8	22	3.2×2.5×2.5 1210 inch	3	130

The parts were up screened from automotive-grade to space use, solder coated, and rated voltage derating applied.

Fig.2 represents the capacity per unit volume for aerospace use and for consumer goods. Aerospace use is equivalent to that it has reached the level of consumer goods in year 2000.

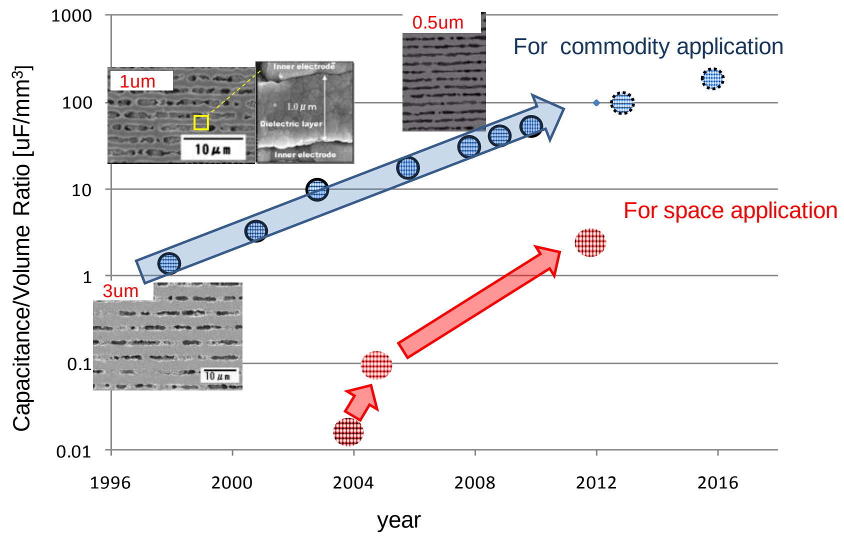


Fig.2　The capacity per unit volume

2.Technology of microstructure

Fig.3 represents a process of MLCC for aerospace.

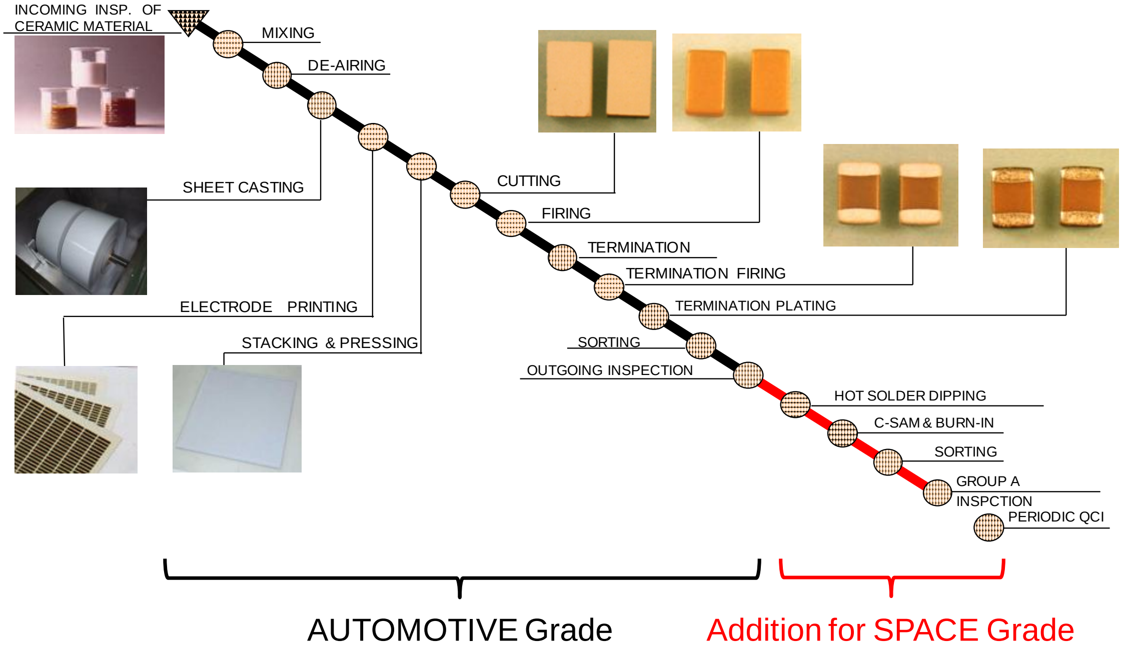


Fig.3 Process of MLCC for aerospace

From ceramic powder mixing process to measurement process, the process for automotive grade products is applied.

Then, from hot solder dipping to group A inspection, a process to space use is added.

It needs micro material control technology for production Small Size and High capacitance MLCC. First technology is the refined and uniformity of inner electrode.

Second technology is the making of a sufficient number of grain and high density ceramic sheet. The 3rd technology is the control moving oxygen vacancies.(Fig.4)

These three technologies are described in the follwing

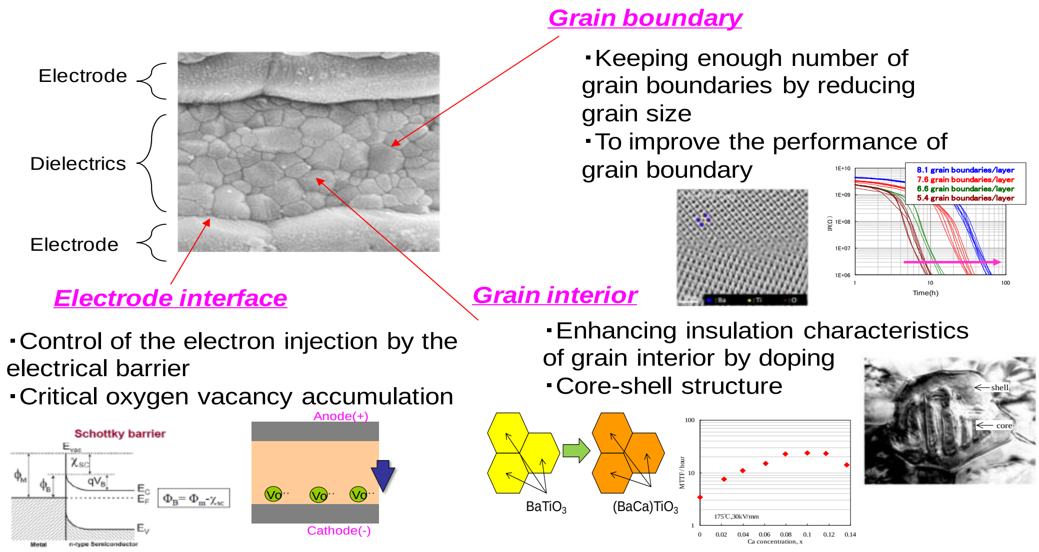


Fig.4 Micro control technology

2.1 Inner-Electrode Technology

Fig.5 shows analyzing a sample that caused the initial failure. It is considered to have failed by dielectric breakdown caused by cohered inner electrode and void.

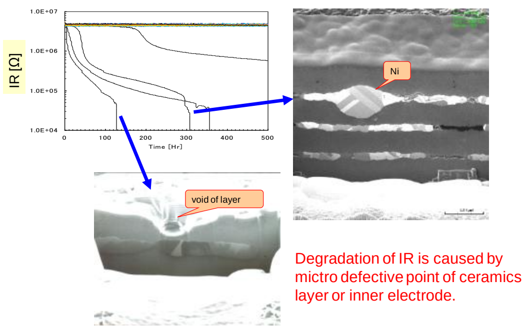


Fig.5 Analysis of IR degradation component

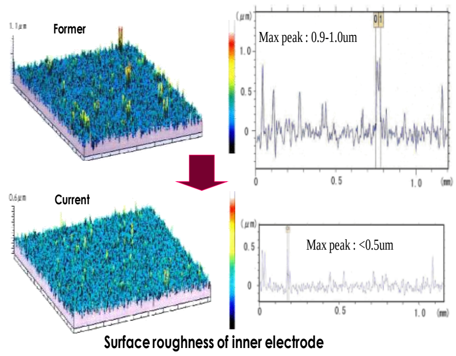


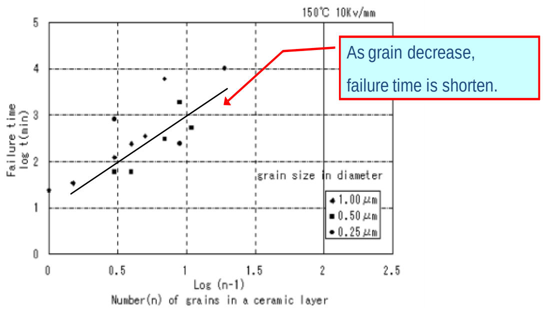
Fig.6 Uniformity of composition

Fig.6 represents the unevenness of printed electrode. This irregularity can cause local thickening of the internal electrode. Irregularity could be reduced to less than half of the former printing process.

2.2 Ceramic-sheet Technology

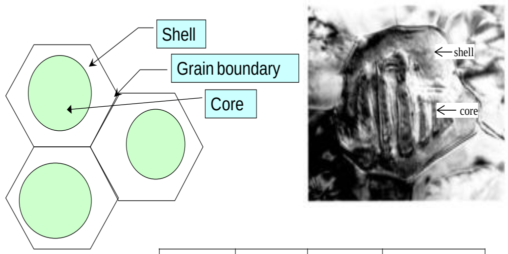
Fig.7 shows the relationship between the time to failure and the number of grains of ceramics. The time to failure shortens when the number of grains is small.

This is caused by the Core -shell structure. The volume resistivity is determined by core, shell and the grain boundary. IR will decrease if shell and grain boundaries are thin and insufficiently generated (see Fig.8).



component reliability have correlation with the number of ceramics

Fig.7 Failure time vs number of grains



	Core	Shell	Boundary
ρ (Ωcm)	10^{11}	10^{13}	10^{14}

Thinner Shell ⇒ Low IR

Fig.8 Core-shell micro structure

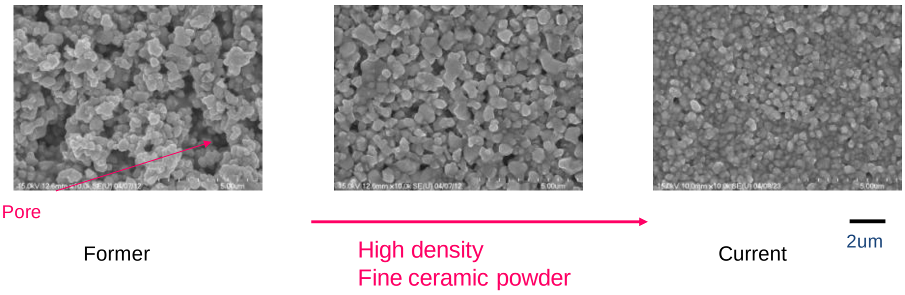


Fig.9 FE-SEM: Surface of green film

Therefore, we are increasing the number of grains by fine ceramic particle size and high density ceramic sheets. (Fig.9)

2.3 Oxygen vacancy Control Technology

The mechanism of wear-out failures shown in Fig.10. When Ni electrode and the ceramic are fired in a low oxygen atmosphere, oxygen vacancies will occur. Because of Oxygen vacancies have positive charge, oxygen vacancies move to the cathode gradually under DC voltage condition.

When a certain energy level is exceeded, electrons are supplied by Schottky emission and deteriorate insulation resistance, finally becoming a wear-out failure.

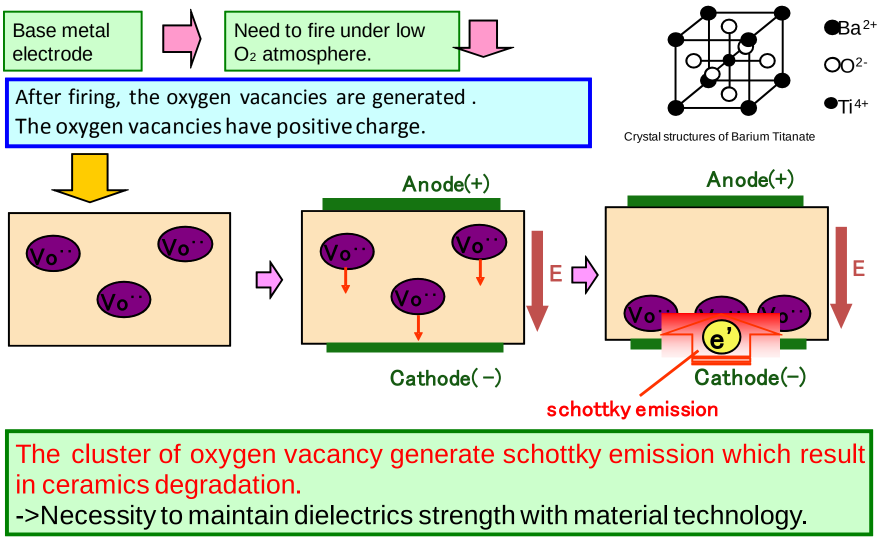


Fig.10 Improvement of micro structure to prolong wear-out

Fig.11 shows oxygen vacancies before and after high temperature load testing by Cathode Luminescence. We confirm that vacancies moved to the cathode side.

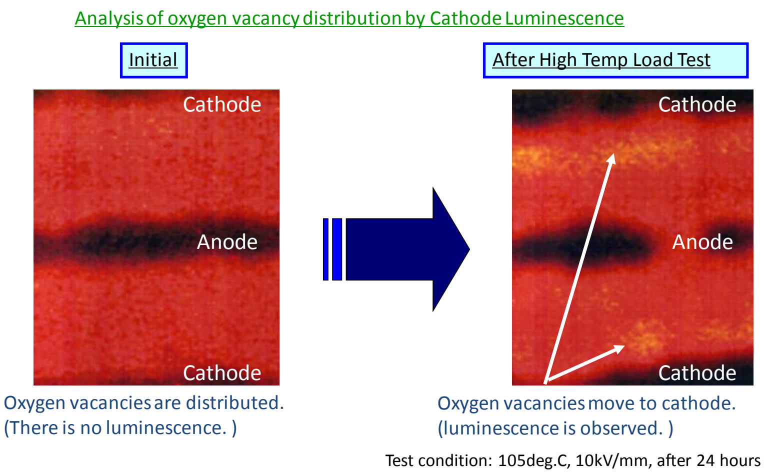


Fig. 11 Observation of oxygen vacancies under high temperature load condition

Fig.12 is an image diagram for the suppression of the movement of oxygen vacancies. Oxygen vacancies are generated during firing. Therefore, rare-earth doping is used to displace Ba site of ceramic structure, generate a Barium vacancy. Oxygen vacancy joins Barium vacancies and oxygen vacancies movement will be suppressed.

However, oxygen vacancies can move to the cathode side under high temperature and high voltage conditions during very long time operation.

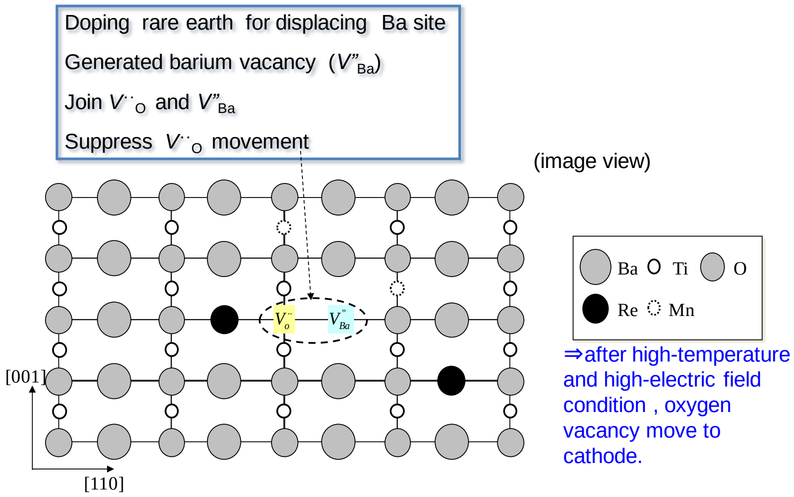


Fig.12 Effect of suppressing oxygen vacancy(v"o) movement by Rare earth doping

3. Conclusion

In summary that so far, the first thing you need is uniformity. This is the technology required for the raw material sheet internal electrode, high-density sheets, and grain of ceramic.

Secondly, a technique to control the grain boundaries and the characteristics of the ceramic.

Thirdly, it is possible to control the internal stress and calcination reaction process.

Fourth, processing technology to prevent contamination by foreign material, is required to control defect rates in order of ppb or less.

Fifth, the development of a material having a high dielectric constant.

It is not only this, but above is the main technology to achieve a small size, high capacity and high reliability capacitor.