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NEW X7 CERAMIC DIELECTRICS FOR MULTILAYER CAPACITORS

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Based on multiphase composition low sintering X7R dielectrics with permittivity of 3800 and X7D dielectrics with permittivity of 1550 were developed. These materials can well contribute to MLC size reduction.

1. Introduction

Ceramic capacitors are one of the basic components in electronics. Developed originally for military purposes, they now have found use in all areas of electronics, including home appliances and industrial and communication devices. The market share of the MLC condenser type is still growing and estimated to rise to 65% of the European ceramic capacitor market by 1995 (Frost & Sullivan). The MLC fits the demands of massproduction and contributes well to device miniaturization. Research is still done to make the MLC compacter, higher in capacity, less expensive and more reliable, mainly by improving the dielectric and electrode materials. The presentation will briefly discuss the situation concerning X7 ceramic dielectrics.

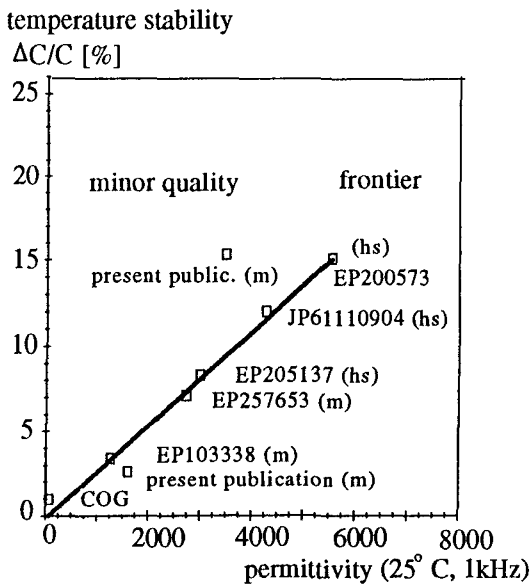

Figure 1 : Correlation between temperature stability of permittivity and permittivity itself corresponding to an analysis of patent applications. The indicated applications (mostly japanese applicants) represent the frontier of combining highest permittivity with highest temperature stability. Denotations : m - multiphase material, hs - high sintering material.

2. The state of the art materials

High temperature stability of permittivity and high level of permittivity itself are contrary demands. We have been analysing these two material properties corresponding to recent patent applications and made an interesting finding. Top material properties define a certain frontier line, as indicated in figure 1. In the stability range > 10 % the frontier is defined by high sintering materials, excluding low cost internal electrodes.

3. Advanced X7 - materials

It is known, that temperature stability can be improved by using and tailoring multiphase materials with core - shell microstructure /1,2,3/. Shell forming phases on $BaTiO_3$ cores are, for example, Bi- layer-structure oxid /4/ and Pb-perovskites /5/. The core - shell formation is explained by liquid phase sintering and the formation of a very dense interface between $BaTiO_3$ and Pb - perovskites, preventing the homogenization of the two ferroelectrics. This type of microstructure is very stabil and might be seen as self organizing structure. The micrograph in figure 2 shows core - shell formation. Elemental maps (figure 3) establish the TEM inspection, additionally.

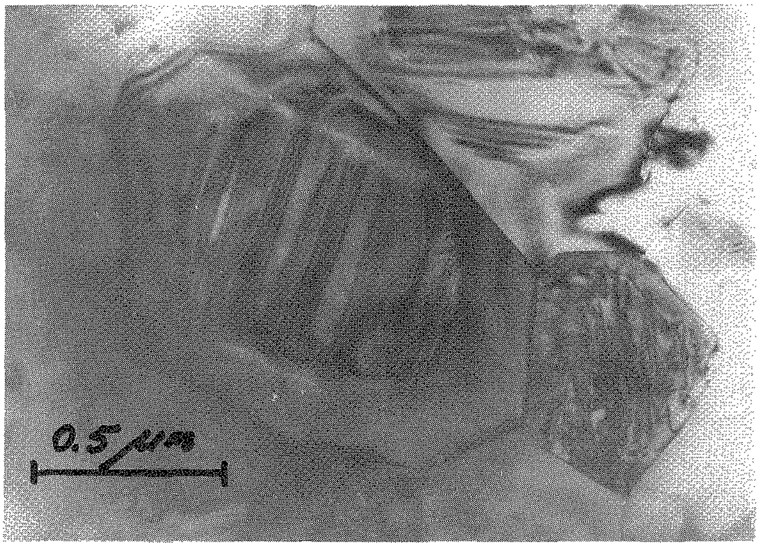

Figure 2 : TEM micrograph showing the grain size and core-shell structure. Within the $BaTiO_3$ core ferroelectric domains are found.

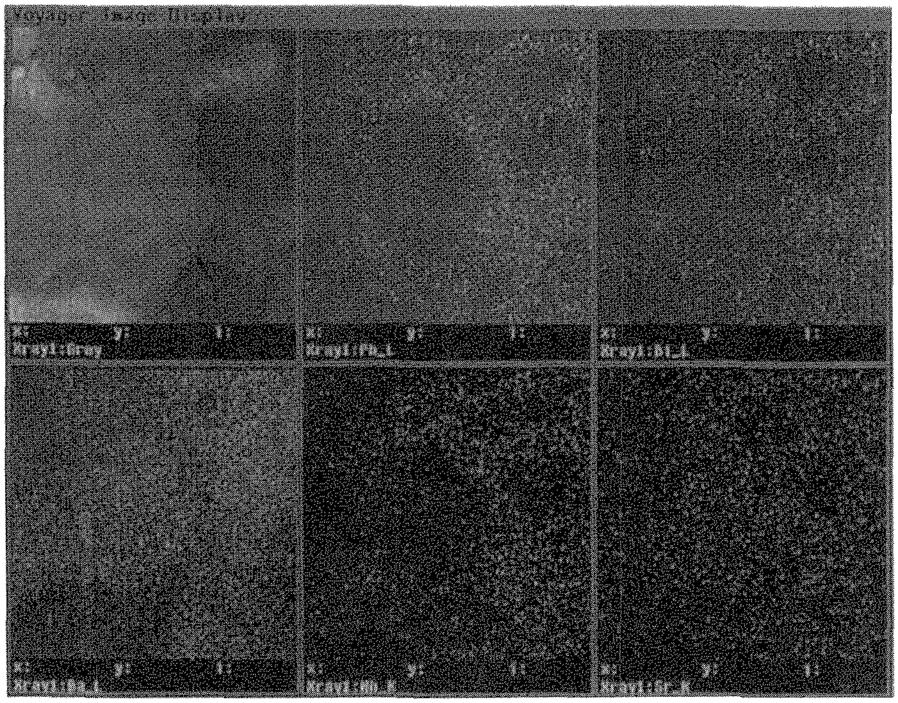

Figure 3: Due to the elemental maps Pb, Bi and Nb are concentrated in the shell area and Ba is concentrated in the core.

Our first aim was to tailor X7R low sintering multiphase material to highest permittivity. The main problems in this process have been : the identification of the intergranular complex perovskite phase and the size regulation of the core- shell structure element. As it is well known, the permittivity of $BaTiO_3$ grains depends strongly on size with maximum at grain diameter in the region 0.7µm to 1 µm. This grain size must be set within the ceramic. It can be done by appropriate raw material selection or processing /3/. The volume fraction of the shell forming perovskite phases was deduced experimentally. It ought to amount about 40 % in accordance with the theoretical ideas of dielectric mixing / 5 /. At optimum conditions we succeded in preparing an X7R dielectric with permittivity of 3800.

Further experiments have shown, that very flat temperature curves of permittivity are obtained , if the shell forming phase is a combination of Bi-layer-structure oxide and Pb-perovskite (figure 4).

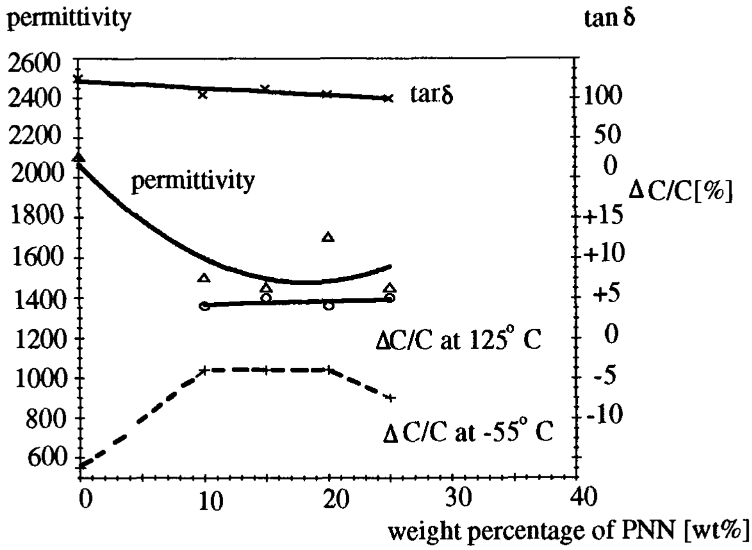

Figure 4 : Results of a series of experiments with variation of PNN content in the material. Sintering conditions : Ts = 1150 °C, t = 2h.

At optimum sintering conditions the following data were obtained on tablets , meeting the X7D classification :

material : $BaTiO_3$, Bi-layer-structure oxid, PNN
sintering temperature : 1120 °C
sintering time : 4 h
permittivity at 25°C , 1 kHz: 1550
tan δ at 25°C, 1 kHz : 1%
ΔC/C within + - 2.5 %
Ris > 10^{12} Ohm

4. Conclusion

Based on multiphase composition with core-shell microstructure low sintering X7R dielectrics with permittivity of 3800 and X7D dielectrics with permittivity of 1550 are possible. The latter would allow the production of ceramic multilayer capacitors with intermediate stability between COG and X7R and drastically reduced size compared to the COG type. The new materials can well contribute to component and thus device miniaturization.

References:

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