Single-layered ceramic capacitors

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ABSTRACT

This presentation shows new generation single-layered ceramic capacitors that are developed using novel colossal dielectric perimittivity materials. The new capacitor uses a single-layer instead of the current multi-layered structure used in X-series and Y-series ceramic capacitors and presents much better performance, such as a low manufacturing cost, better realbility, longer life time and broad temperature-stable range from –190 °C to +180°C, for various applications from microelectronic technology to the automotive, transportation and Space Instrumentation.

Keywords: capacitors, dielectrics, ceramics.

1 INTRODUCTION

Ceramic capacitors are the basic "workhorse" underpinning the entire "high-tech" economy since the number of such components mounted in electronic equipment and electrical systems is larger than any other component type. Several hundred ceramic capacitors, for example, are necessarily assembled into any one mobile phone. The essential driving force behind the market growth in this area is the strong demand for key end-products such as handsets, notebooks, desktop computers, tablets and ultrabooks, TV sets and other consumer AV equipment. The increasing demand for ceramic capacitors from large end-use market segments/industries such as wireless telecommunications, computing, the automobile and power supply industries, renewable energy, telecoms infrastructure, electronics for defense, medical and instrumentation applications, lighting ballasts and the oil and gas industries also drives market growth. The Global Ceramic Markets report shows that the global ceramic capacitor market will reach $17.9 billion annually by 2017 while ever-increasing demand for end-use devices is expected to fuel further growth (~20.6% annually) [1]. Furthermore, the lifetime of such components is on average only three-four years. The market demand for such ceramic capacitor components will therefore never be saturated.

The capacitance of a capacitor is proportional to the dielectric permittivity of the materials. It is evident that the higher the dielectric permittivity of the materials, the smaller the size of the devices and the larger the capacity of the capacitors. Unfortrunately, current ceramic dielectric materials do not have sufficient dielectric permittivity on their own to give a high enough capacitance in a single-layered configuration. Multi-layered ceramic capacitors (MLCCs) thus have to be used. MLCC's consist of numerous ceramic dielectric layers interleaved with metal electrodes with the electrodes connected alternatively to one of two end terminations. Such MLCCs represent the largest component of the currently fabricated ceramic capacitor market but they also have issues related to reliability and durability arising from potential electronic/mechanical fatigue. it is obvious that the single-layered ceramic capacitors have better performance once its capacitance can reach the same level as the MLCCs.

In this presentation, the Australian National University (ANU) reports a new, high performance signle-layed ceramic capacitrors, developed using recently invented new collosal dielectric materials. Such new capacitors are likely to replace the current MLCCs'products.

2 SINGLE-LAYERED CERAMIC CAPACITORS

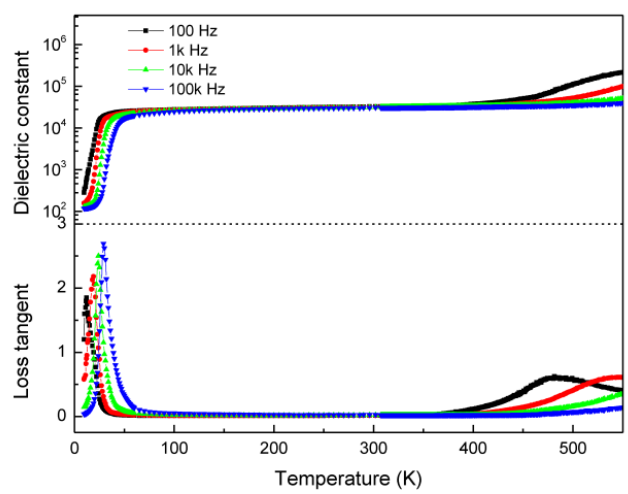

Figure 1 The colossal dielectric property of the invented dielectric materials.

To date, there are a few materials systems which have a dielectric permittivity above 10000. Examples include $BaTiO_3$-like, perovskite relaxor ferroelectric materials, such as $BaTi_{0.9}(Ni, W)_{0.1}O_3$, $Ba(Fe_{0.5}Ta_{0.5})O_3$, $(Ba,Sr)TiO_3$, $Ba(Ti,Sn)O_3$; $CaCu_3Ti_4O_{12}$ (CCTO) as well as analogous

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Component	Dielectric Constant	% Capacitance Change	Dielectric loss
X7R	2000-4000	± 15% -30% (-55 to 125° C)	3.5%
X5R	1000-4000	± 15% (-55 to 88° C)	2.5%
X8R	1000-4000	± 15%- ± 20% (-55 to 150° C)	2.5%
Y5V	>16000	Up to 82% (-30 to 85° C)	9%
ANU	***>10000***	***23% (<±15%) (-190 to 177°C)***	***5% (-190 to 177°C)***

Table 1 Specification of dielectric materials used in X- or Y- type MLCCs and the colossal permittivity materials in ANU's single-layered capacitors as well as their capacitance changes.

compounds like $CdCu_3Ti_4O_{12}$, $Bi_{2/3}Cu_3Ti_4O_{12}$ as well as $La_{0.5}Na_{0.5}Cu_3Ti_4O_{12}$, Li (and/or K), and Ti (and/or V) co-doped NiO, and $La_{1-x}Sr_xNiO_4$ (x=1/3 or 1/8). These materials, generally have either temperature stability and/or high dielectric loss problem.

We have recently introduced the defect chemistry design and invented a high dielectric permittivity material. The new dielectric material has a controllable colossal dielectric permittivity from 10,000-100,000 with better temperature stability and significantly less dielectric loss by comparison with existing colossal dielectric permittivity materials (Fig.1). the results published in the prestigious journal "*Nature Materials*" [2], attracting a significant attention from both Sceince and technology fields.

The biggest advantage of using this new material in ceramic capacitors is that, for the same specification, capacitors need only use a single dielectric layer to achieve a high capacitance. This would not only significantly reduce the manufacturing cost of these components but also considerably improve their lifetime and reliability as it removes the internal metal electrode layers (avoiding the electrical fatigue) used in current MLCCs. This novel dielectric material thus has enormous pot ential for use in new generation, high capacitance capacitors.

The commercially most successful X7R, X5R, Y5V, Y5R, X8R and X7S ceramic capacitors are fabricated by a complicated and relatively expensive MLCC process. The MLCC processing is difficult, complicated and expensive by comparison with other types of ceramic capacitors. For the same specification, the new capacitor uses only a single-layer instead of the current multi-layer structure used in X7R, Y5V and Y5R ceramic capacitors. Table 1 lists the critical specifications of typical high capacitance MLCCs and single-layer prototype capacitors made from the new ANU material. Note that the new capacitor requires only a single-layer instead of the multi-layer structures used in the X- and Y-series ceramic capacitors over the range from 100 pF-2.2 μF and has much better performance. In addition, the new material performs well over the broad temperature range from –190 ^{o}C to ~ +180 ^{o}C. It can be used, for instance, in automotive applications where under-hood temperatures may exceed the 85 °C normal rating, where Y5V and Y5R capacitors cannot be used. The potential of the material as a single layer, high temperature capacitor (up to 150°C) with capacitance an order of magnitude larger than the currently commercialised high temperature X8R capacitor (currently ~0.22 μF) is also considerable. The resultant devices are anticipated to lead to a *new generation* of high capacitance ceramic capacitors. High capacitance ceramic capacitors have a great potential to replace currently existing high capacitance MLCCs for uses typically in power supply decoupling, telecommunications, solar inverters, wind turbines, computers and miscellaneous instrumentation.

3 FUTURE WORK

We have developed prototype single-layered cermic capaacitors with excellent performance. We are now in the process to promote the commercial pathway. That includes (1) the development of the scale-up preparation approach of the invented dielectric material, selection of the electrode materials via the investigation of the structural/property matching and aging characterisation. And (2) the development of capacitor devices, respectively, this will cover (a) the fabrication of the capacitor devices as well as the optimisation of associated processing conditions, (b) the development of instrument and facility for device specification characterisation, and (c) various specification characterisations, such as the capacitance, capacitance fluctuation at different voltage and different temperatures, dissipation factor, insulation resistance at different temperature and different voltages, temperature stability, thermal ageing, electrical fatigue, breakdown voltage, leaky current, mechanical loading test, thermal shocking test.

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