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Developments in ferroelectric ceramics for capacitor applications

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Abstract. A brief overview of the materials and processes for making ceramic capacitors based on $BaTiO_3$ and relaxor ferroelectric compositions is presented with special emphasis on more recent developments.

Keywords. Ferroelectric ceramics; ceramic capacitors; barium titanate; relaxor ferroelectrics.

1. Introduction

The last few decades have witnessed an ever increasing interest in ferroelectric ceramics because of their applications in a wide range of devices. Ferroelectric ceramics possess extremely high dielectric constant which makes them unenviable for making miniaturized single- and multi-layer capacitors. The excellent electromechanical response of these ceramics, on the other hand, is currently being utilized in a large number of devices such as sonars, high voltage generators, resonators, flaw detectors, lighters, actuators and micro-positioners. When doped with suitable off-valent cations, these ceramics exhibit semiconducting behaviour. In such semiconducting ferroelectric ceramics, the interaction of electrical transport with ferroelectricity near Curie point leads to nonlinear positive temperature coefficient of resistance (PTCR-effect) which is being commercially exploited in PTC-thermistors. The pyroelectric and electro-optic properties of these ceramics are no less interesting. These properties, however, have not been as much commercially exploited as the other properties mentioned earlier. Potential applications envisaged are in IR imaging and detection, goggles for avoiding flash-blindness, optical displays and optical modulations. The remanence behaviour has been shown recently to be useful for non-volatile RAM cells operating at a few volts.

As a result of intensive research activity, the topic of ferroelectric ceramics has acquired the level of a subject with an extremely large number of publications and patents coming out year after year. It is impossible to do justice to this subject in a short overview. We, therefore, restrict ourselves to a few important developments in materials and processes relevant for capacitor applications. Here again, we have not attempted to cover barrier-layer capacitors since these are based on ferroelectric and non-ferroelectric materials as well and deserve a full article of present length.

2. Barium titanate-based ceramic capacitors

As is well known, $BaTiO_3$ ceramics possess very high dielectric constant with relatively low dissipation factor. However, a severe limitation of this material in pure form for making capacitors is the high temperature coefficient of dielectric constant in the vicinity of the cubic to tetragonal phase transition. In this section, we discuss the two different strategies based on (i) grain refinement and (ii) solid solution formation which have been used to overcome this limitation.