Comparative study of lead-free and lead-based piezoelectric multilayer elements

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Piezoelectric multilayer elements are used for a variety of applications because they offer high piezoelectric performance in combination with low driving voltages. The market is dominated by lead-based materials containing more than 60 wt% lead. Since lead is highly toxic to both humans and ecosystems, it has become an environmental concern to replace such materials by non-toxic materials. In recent years, several candidate materials have been proposed and studied extensively, e.g. various alkaline niobates. The basic knowledge related to the synthesis and properties of these new materials has been developed rapidly and has paved the way for studies more related to the commercial manufacturing and practical use of industrial products.

We have prepared and tested multilayer piezoelectric elements made of lead-free (Sr-doped KNN) and lead-based (PZT and PMN-PT) materials. All the elements have nearly the same geometry; 9x28 mm rectangles with three layers, each layer being 80-120 μm thick. The elements have been prepared by conventional tape casting and lamination techniques from powders manufactured by the mixed oxides route similar to methods applied in industry. The microstructure of the components has been characterised by electron microscopy techniques and x-ray diffraction, and their mechanical properties have been determined by nanoindentation. The polarisation and strain hysteresis have been recorded. An equivalent electrical circuit model (KLM) has been extended and used to characterise the electromechanical properties in thickness mode, and the electrical impedances as a function of frequency have been measured. Theoretical impedances have been calculated with the KLM scheme and by a fitting process, and the thickness mode parameters have been deduced.