Lead-free piezoelectric thick films based on potassium sodium niobate solutions

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ABSTRACT

Lead-based piezoelectric materials such as lead zirconate titanate ($Pb(Zr_x,Ti_{1-x})O_3$ or PZT) and lead metaniobate ($PbNb_2O_6$) are the most widely used materials nowadays in the market for piezoelectric application, including recently developed thick films based devices, because of their excellent piezoelectric properties, good reproducibility, and low production cost. At the same time, the high lead toxicity, problems with the recycling and disposal of piezoelectric devices containing lead have inspired wide investigations of the lead-free piezoelectric materials. The necessity in development of biocompatible piezoelectric materials for the medical applications has additionally motivated an activity in the field of lead-free piezoelectrics.

In present work, the processing route for $(K_{0.5-x/2}Na_{0.5-x/2}Li_x)(Nb_{1-y}Ta_y)O_3$ (KNN-LT) based lead-free piezoelectric ceramic powder, which can be sintered at lower temperatures and therefore used for the thick film production, has been developed. The possibility of screen printing lead-free piezoelectric thick films has been demonstrated by manufacturing a number of different structures on two types of substrates: alumina substrates for showing the compatibility of KNN and the screen printing technology, and porous substrates (acoustically engineered KNN bulk ceramics) for manufacturing a lead-free thick film based high frequency transducer. Fine powder of Li- and Ta-modified KNN, and other commercial available ingredients were used to manufacture a paste, which is compatible with the screen printing technique. The lead free thick films were pressed in green state with a cold isostatic press (CIP) to obtain high green state density. Problems with humidity, moisture and polarisation are discussed, evaluated and a well suited solution is obtained.

Lead-free thick films prepared have been characterised using several methods. The ferroelectric activity of the piezoelectric material has been determined by the Sawyer-Tower setup. d_{33}-piezo-meter, impedance analyzer and pulse echo system (in case of the acoustic transducers) have been utilised in order to measure the chosen properties of the material and the test devices. Microstructure characterisation has been carried out with a scanning electron microscope. The measured (effective) d_{33} piezoelectric coefficient of the investigated lead-free KNN thick films is equal to 80 pC/N. Moreover it has been demonstrated that the developed material is fully compatible with the screen printing technology. According to the best knowledge of the authors these results are the most successful and one of the few published results on lead-free piezoelectric thick films.