Lead-free piezoceramic material in an industrial application

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Over the course of the last 20 years, lead-free piezoelectric materials have gone from being a noble objective to distinct products. Current state of the art lead-free piezoelectric materials represent different families of materials, including barium titanate ($BaTiO_3$ or BT), potassium sodium niobate ($(K_xNa_{1-x})NbO_3$ or KNN), lithium sodium niobate ($(Li_{1-x}Na_x)NbO_3$ or LNN), bismuth sodium titanate ($(Bi_{0.5}Na_{0.5})TiO_3$ or BNT). Most of these materials have been investigated intensively during the last 10-20 years, showing very promising results in some cases. However, when it comes to industrial applications and/or high scale production, a number of issues may arise that are typically not addressed at lab scale. Therefore, industrialization of lead-free materials, as well as their practical application in a real working environment is of major concern.

In this work, a KNN-type material has been developed for an industrial sensor application. The manufacturing process has been adapted to medium scale production (up to 100 kg per year). However, a number of challenges have been faced, including the environmental challenges due to high utilization of organic solvents during the manufacturing process.

A number of vibration sensors have been built based on the material developed and characterized in a wide temperature range. An acceptable performance of the sensor has been obtained at room temperature, along with an extended working temperature range when compared to PZT based sensors, but a number of issues have been observed. Thermal stability and anomalies of the sensor output signal over the working temperature range are some of the most crucial sensor characteristics and serious shortcomings were seen in the case of the developed lead-free based sensors. The sensor signal output has shown a significant drop at elevated temperatures, making the application of the lead-free material developed challenging if not impossible, even though the performance of the sensor at room temperature is comparable with PZT based sensors. It has therefore been concluded that the development of lead-free materials should be carried out in a close collaboration with end-users. The scalability of the manufacturing process as well as the cost of the material should always be considered as well.