A low-cost alternative lead-free piezoelectric LiNbO3 films for micro-energy sources

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Energy harvesting and ultra-low power electronics are urgently needed for the implementation of self-powered, battery- and maintenance-free sensors. The integrated solutions with an energy harvester are highly demanded in the market of the Internet of Things, health monitoring, and more generally 4.0 industry. Vibrational energy harvesting is frequently considered as an alternative solution to photovoltaics for this purpose. Pb-containing piezoelectric materials, such as $PbZr_{1-x}Ti_xO_3$ (PZT) ceramics, are usually considered as the best performing electro-mechanical transducers. Despite the outstanding results, these devices are still exploiting Pb-based materials that represent an environmental issue and do not respect REACH and RoHS regulations in EU. On the other hand, Pb-free materials have also been investigated for applications at a low acceleration and a low excitation frequency. One of the highest performances was obtained for AlN devices, which is capable of working at 58Hz and generating 63 μW at 0.7g. Lead-free $LiNbO_3$ (LN) has been little studied for the piezoelectric energy harvesting applications. Although it is a cheap piezoelectric material without lead and toxic elements, it beneficiates of technological maturity in single crystal fabrication for optical and acoustic applications. In this work LN is considered as a potential substitute to lead-based piezoelectric materials for vibrational energy harvesting applications. We present a viable technology to implement a thick single crystal films on silicon or metal substrates with optimized clamped capacitance for impedance matching conditions (Fig. 1). The generated power density by our device, based on thick Y128°-LN films on Si substrates fabricated by bonding/polishing technique, was 965 μW/cm^2/g^2 (at excitation of 105 Hz and acceleration of 0.1 g), which is among the highest reported values compared to both Pb- and Pb-free vibrational harvesting devices (Fig. 1) [1,2]. The harvesting capabilities of the device allowed starting a sensor node and sending data under continuous resonant excitation (fig 1,[3]).

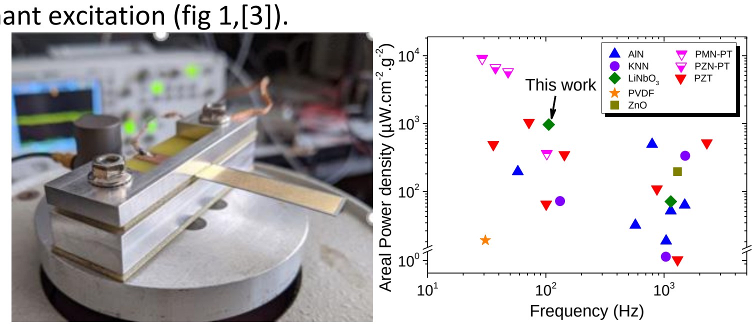

Fig 1: Photo of cantilever made of $LiNbO_3$/stainless steel (left). *Comparison of energy recovery performance of different lead-based and lead-free piezoelectric materials as a function of vibration frequency (right).*

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