Title: Reliability of High Performance Piezoactuators: Material developments and studies on electrical properties

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Abstract

Piezoelectric materials based on ferroelectric lead zirconate titanate Pb(ZrₓT盛世ₐ₋ₓ)O₃, also known as PZT, are employed in numerous devices such as transducers, resonators, sensors, non-volatile memories, nanopositioners or actuators. Multilayer piezoactuators, for example, are used for direct fuel injection in both diesel and gasoline engines, respectively. Still increasing standards with respect to e.g. performance and reliability are demanded of such ceramic components and they can only be satisfied by in-depth understanding all used materials as well as the application itself.

In this contribution, the development of multilayer piezoactuators from devices with Ag/Pd inner electrodes to the currently 3rd generation of PZT stacks with copper electrodes will be presented. Corresponding material related aspects, innovative design and new processing strategies of the PZT actuators resulting in e.g. no polarization cracks and further possible downscaling while exhibiting significantly enhanced reliability at high number of cycles upon load, temperatures up to 190°C and high humidity will be discussed.

Furthermore, results on the resistance degradation study of neodymium-doped PZT layers with Ag/Pd electrodes investigated when applying electrical field strengths of 0.25 – 1.25 kV/cm at temperatures between 390 – 530°C will be presented and discussed in terms of defect chemistry. The behavior was studied on two time scales. Conductivity variations on a short-time scale are interpreted in terms of field induced oxygen vacancy concentration changes (stoichiometry polarization). Increase of the current by several orders of magnitude during long-time load was associated with phenomena including cations. The highly conductive state of the degraded PZT layers could be maintained by quenching the samples down to room temperature and showed a metal-like behavior. Such highly conductive layers were further studied by means of impedance spectroscopy and several other analytical methods: Depth-profiling experiments by gradual polishing and laterally resolved conductivity measurements using microelectrodes revealed existence of individual current paths in the bulk of the degraded PZT layers. It is shown by means of scanning electron microscopy, energy dispersive X-ray spectroscopy, laser ablation – inductively coupled plasma – mass spectrometry and conductive atomic force microscopy that the highly conductive paths/filaments consist of silver, are strongly localized to grain boundaries and directly responsible for a metal-like connection between the anode and cathode. Interestingly, formation of these paths starts at the anode. This indicates existence of a novel mode of resistance degradation at high temperatures without impact of humidity. In accordance with all results, a detailed degradation mechanism is suggested.

Biography

Dr. Lukas Andrejs joined TDK-EPC Deutschlandsberg in the field of piezo and protection devices in 2014. He came from the Austrian Institute of Technology, where he was concerned with battery materials research, especially with modern ceramic Li-ion conductors. Dr. Andrejs graduated at the Vienna University of Technology (Vienna, Austria) with concentration on chemistry and technology of materials in 2008. His diploma thesis was carried out in close cooperation with TDK-EPC Deutschlandsberg (former EPCOS OHG) and the Graz University of Technology where he also attended a parallel study program between 2007 and 2008. His dissertation, which he completed at the Christian Doppler Laboratory for Ferroic Materials at Vienna University of Technology in 2012, is in the area of solid state electrochemistry and defect chemistry and focuses on the behavior of donor-doped lead-zirconate-titanate (PZT) upon DC load and the study on the charge transport at enhanced temperatures in this perovskite-type electroceramics by means of impedance spectroscopy.