Evaluation of the Toughness Anisotropy in PZT-based Multilayered Actuators

R. Bermejo[1,2], H. Grünbichler[1], J. Kreith[2], R. Danzer[1,2]

[1]Institut für Struktur- und Funktionskeramik, Montanuniversität Leoben, Peter Tunner-Straße 5, A-8700 Leoben

[2]Materials Center Leoben Forschung GmbH, Roseggerstraße 12, A-8700 Leoben

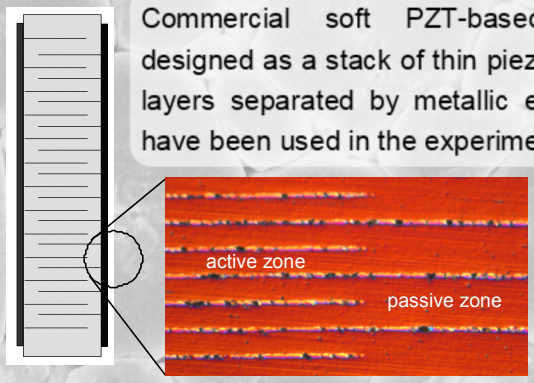
Introduction

Lead Zirconate Titanate (PZT)-based ceramics are used in the fabrication of multilayer piezoelectric actuators (MPAs) for modern fuel injection systems. The sintering, poling process and service conditions of MPAs influence the mechanical properties of the piezo-ceramic as compared to those of the bulk material.

The aim of this work is to assess the crack growth resistance anisotropy of the piezo-ceramic material when the MPA is loaded under compression, which simulates to some extent the mechanical response of such components in service.

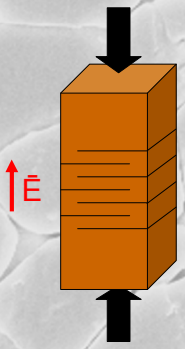
Material of study

Commercial soft PZT-based MPAs, designed as a stack of thin piezo-ceramic layers separated by metallic electrodes, have been used in the experiments.



Detail of the active and passive zone of a MPA

Experimental procedure



Poling process

Pre-stressed in compression and electrically poled with an E-field of 2 kV/mm.

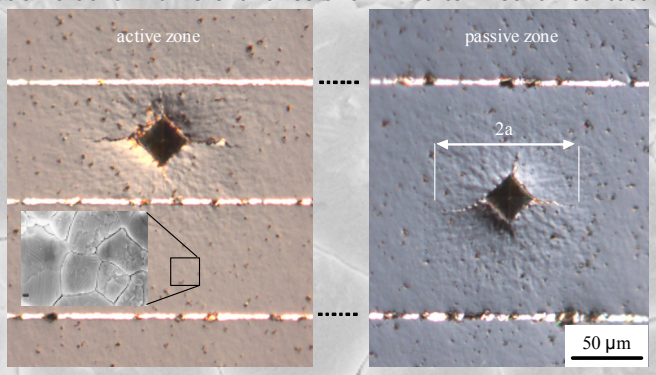
Mechanical testing

Mechanical loaded in compression along the longitudinal axis (partially depolarisation).

Indentation tests

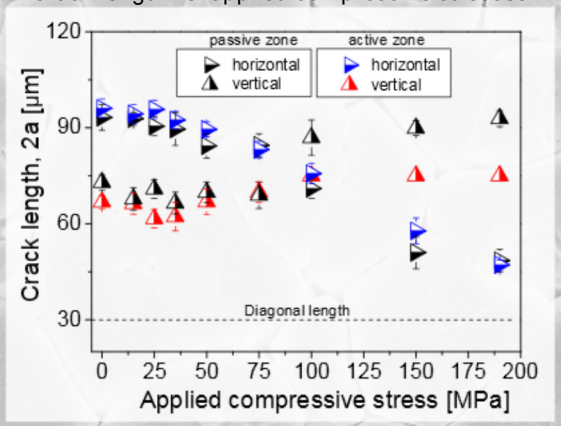
Vickers indentations of P = 1.96 N in the active and passive zone of the MPA after mechanical testing.

Indentation cracks in different zones of a MPA after mechanical testing



Results and conclusions

Crack length vs. applied compressive stresses



$$K_R = \chi \cdot \frac{P}{c^{3/2}}$$

K_R = Fracture resistance

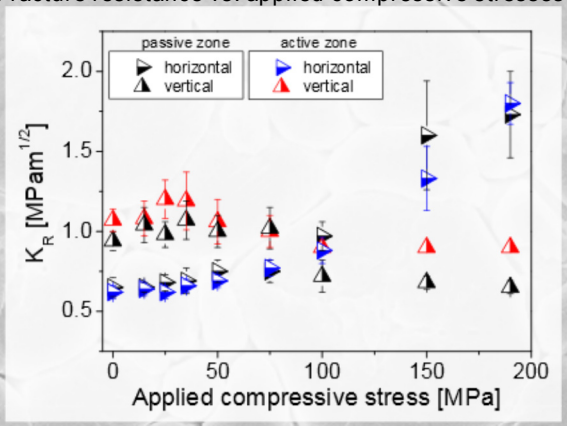
P = Indentation load

c = Measured crack length

χ = Crack shape factor (0.105 ± 0.008)§

§ Value calibrated with bulk-PTZ material using the SEVNB method

Fracture resistance vs. applied compressive stresses



Indentation experiments show a clear anisotropy (parallel or normal to the poling direction) in the resistance to crack propagation of the piezo-ceramic used in MPAs. The depolarisation process (domain switching owed to the ferroelastic effect) experienced in the poled actuator due to the applied mechanical loading can be clear evidenced for compressive stresses greater than 50 MPa, leading to a maximum fracture resistance value as large as 1.70 MPam$^{1/2}$.

Acknowledgements

Financial support by the Österreichische Forschungsförderungsgesellschaft mbH, the Province of Styria, the Steirische Wirtschaftsförderungsgesellschaft mbH and the Municipality of Leoben within research activities of the Materials Center Leoben under the frame of the Austrian Kplus Competence Center Programme is gratefully acknowledged. The authors thank the company EPCOS OHG, Deutschlandsberg, Austria, for providing the material for this investigation.