Motivation, Methods and Objectives

Volatility of lead oxide creates inhomoegenous sintering atmosphere in industrial sized furnaces, therefore effects of variation in PbO content are relevant for quality of PZT multilayer actuators. Two lines of investigations on effects resulting from PbO content variation were followed:

(i) preparation of soft doped PZT ceramics with batch PbO content varying from 2 mol% deficit to 2 mol% PbO excess and 
(ii) fabrication of PZT multilayer actuators under different sintering setups providing different PbO vapor pressure and mass losses during sintering.

Both ceramics and actuators were characterized by SEM, XRD and measurements of dielectric low field and high field strain. Objectives of the work are (i) to point out the effects of PbO content variation on properties of the PZT ceramics and devices, (ii) to gain first insight in the mechanism leading to changes with variation in PbO content and (iii) to establish correlations between sintering weight loss and important parameters for performance of PZT.

Ceramics prepared with varying PbO content

PbO-content in batch composition varying from 2 mol% deficit to 2 mol% PbO excess

PbO peaks in X-ray diffraction patterns can be detected for PZT > 2 mol% PbO excess. In ceramics with PbO deficit occurs the formation ZrO2. Similar grain size for PZT ceramics with PbO excess and deficit

Dielectric properties and high-field strain

In ceramics with PbO deficit occurs the formation ZrO2 secondary phase PbO peaks in X-ray diffraction patterns can be detected for PZT > 2 mol% PbO excess. Shift of PZT structure to more tetragonal structure with decrease in PbO content

In ceramics, there are only slight effects from grain size, but very strong influence is the same for bulk ceramic specimens and for multilayer actuators.

Actuators fabricated using different sintering setups

Laboratory Sintering Setups: commercial soft PZT, 1/4 actuators encapsulated, standing atmosphere, progressive PbO contamination

Higher loading of crucibles (4 vs. 1 actuators) results in lower sintering mass losses

Dielectric properties and high-field strain

Linear negative correlation between weight loss and dielectric loss tan δ

Linear positive correlation between weight loss and high field strain

Strong influence of PbO-content on electric properties of actuators

Strong influence of mechanical preload on high field strain

Conclusions

Lead oxide content markedly influences electrical properties of PZT. The influence is the same for bulk ceramic specimens and for multilayer actuators. Most significant correlations are an increase in high field strain and a decrease in dielectric losses with lower PbO content.

In ceramics, there are only slight effects from grain size, but very pronounced effects from changes in structure.

In actuators, a mechanical preload of up to 30 MPa strongly enhances the high field strain independent of PbO content.