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Influence of Lead Oxide Stoichiometry Microstructure and Characteristics of PZT Ceramics and Multilayer Actuators

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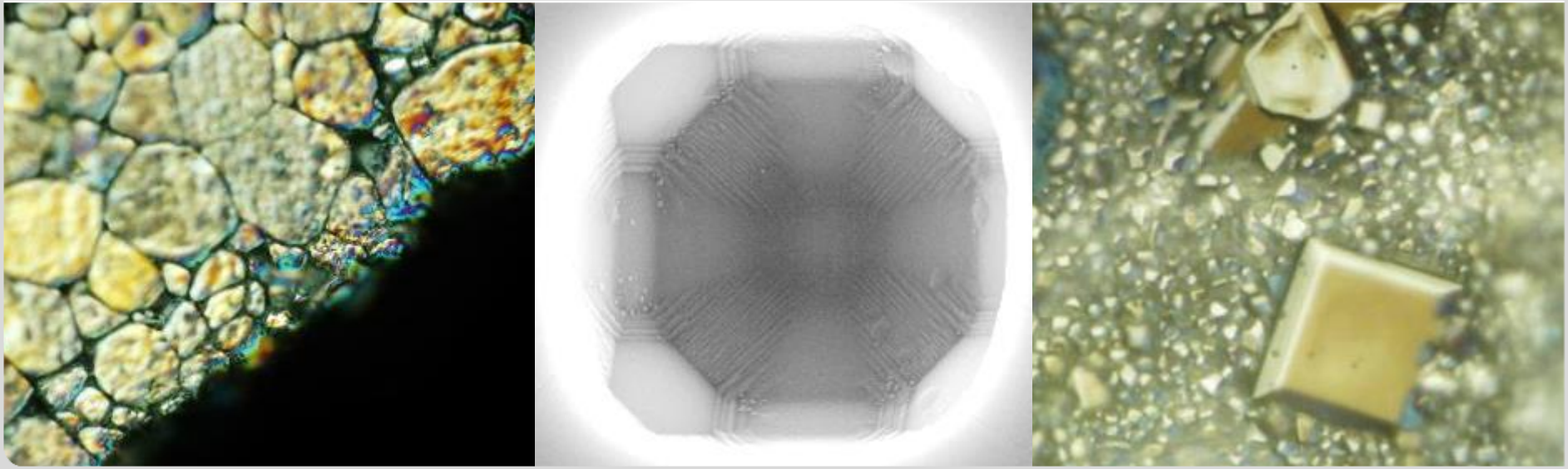
INSTITUTE FOR APPLIED MATERIALS

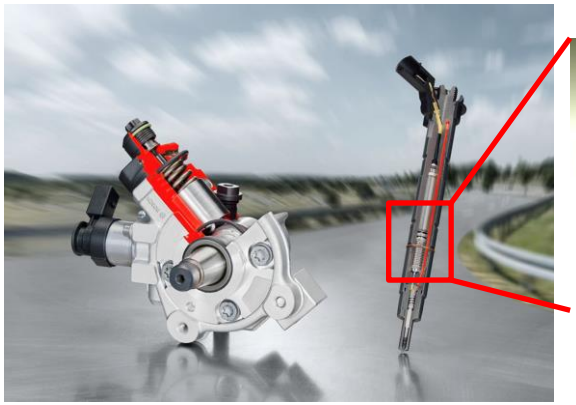


Outline

- Introduction
- Sintering experiments on multilayer actuators
  - Control of the sintering mass loss
  - Electrical characterization
- Comparison to bulk specimens
  - Structure
  - Electrical characterization

Introduction

- Multilayer PZT actuators
  - Commonly used in fuel injection systems



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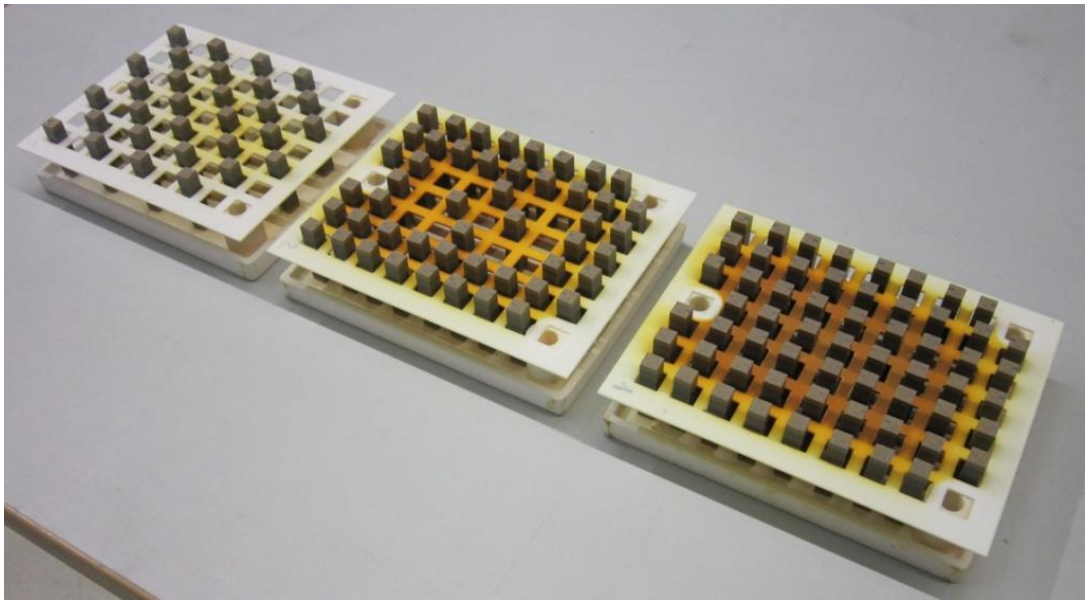
- Industrial sintering of actuators
  - Both batch and continuous firing are in use
  - Different evaporation of PbO
    - Variation of the local sintering atmosphere
  - Strong influence on actuator performance

>15 % variation in strain!



PZT material used for actuators

- Powder composition
  - $Pb(Zr_{0,53}Ti_{0,47})O_3$ + 2mol% $Sr(K_{0,25}Nb_{0,75})O_3$
  - 2mol% PbO excess
    - 1.38 ma%
- Actuators
  - 330 layers
  - 85µm thick
  - AgPd electrodes
  - Actuator processing by Bosch

- **Sintering of actuators in laboratory scale**
- **Control of the PbO loss during sintering**

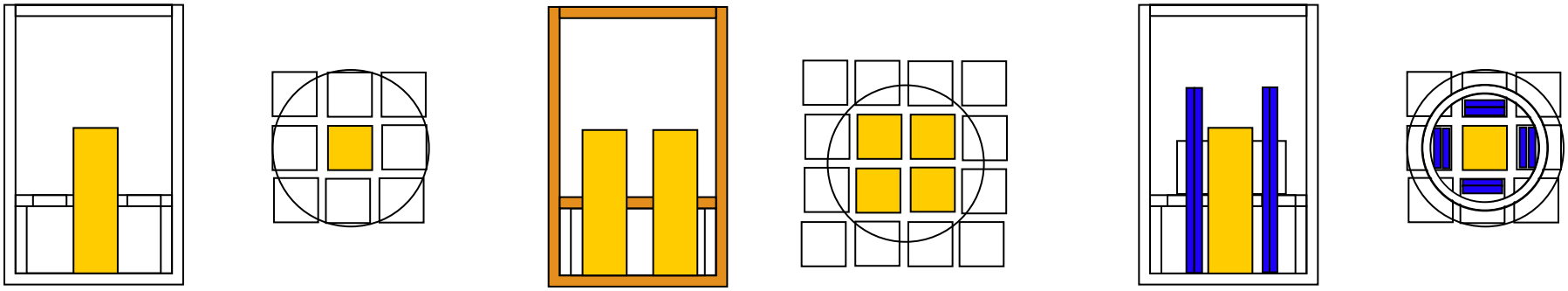
- Sintering experiments on multilayer actuators

Sintering Setups for Multilayer Actuators

Setup 1
Non precontaminated crucible
1 Actuator batches

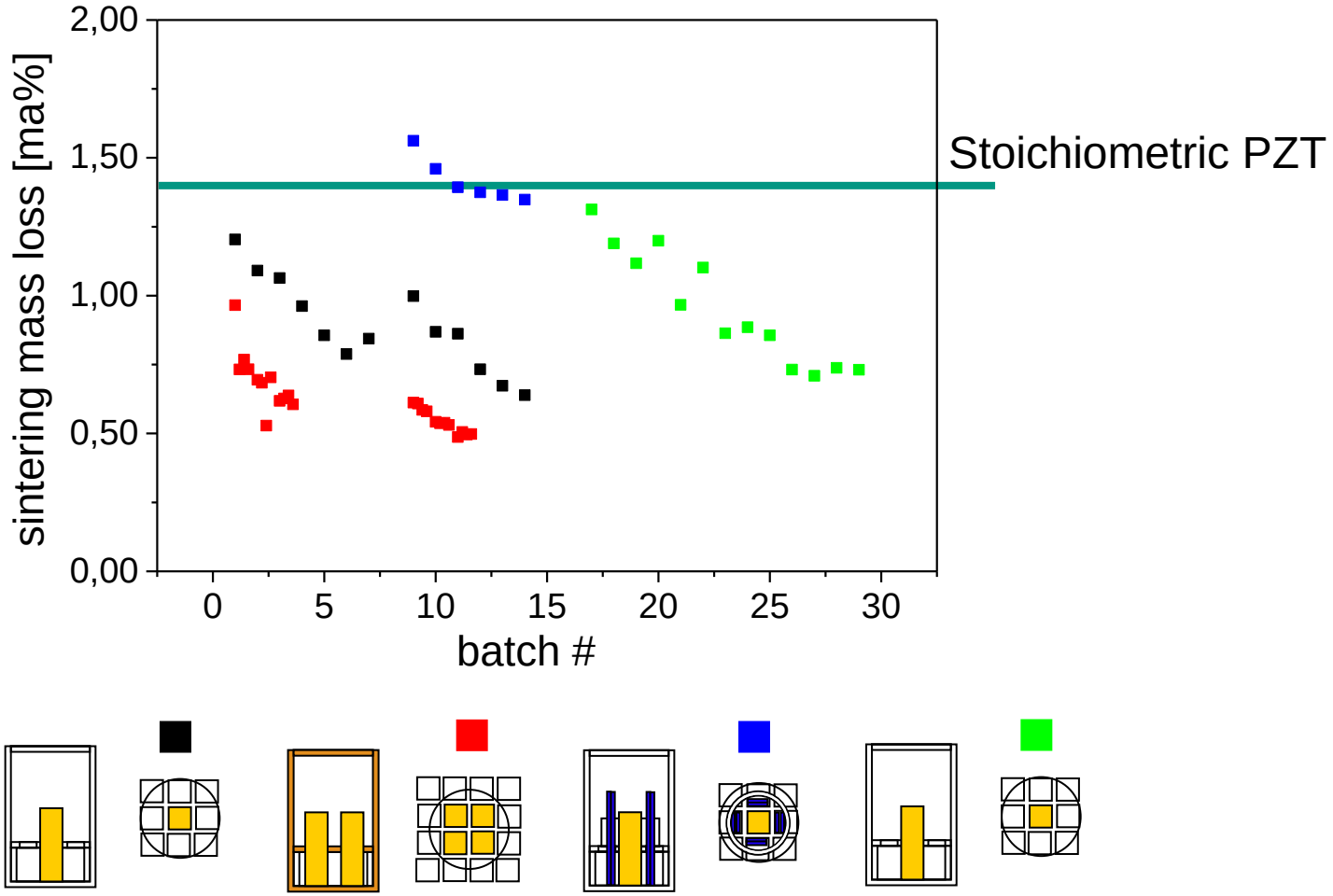
Setup 2
Precontaminated crucible
4 Actuator batches

Setup 3
Non precontaminated crucible
1 Actuator batches
Additional getter plates (16.5g)

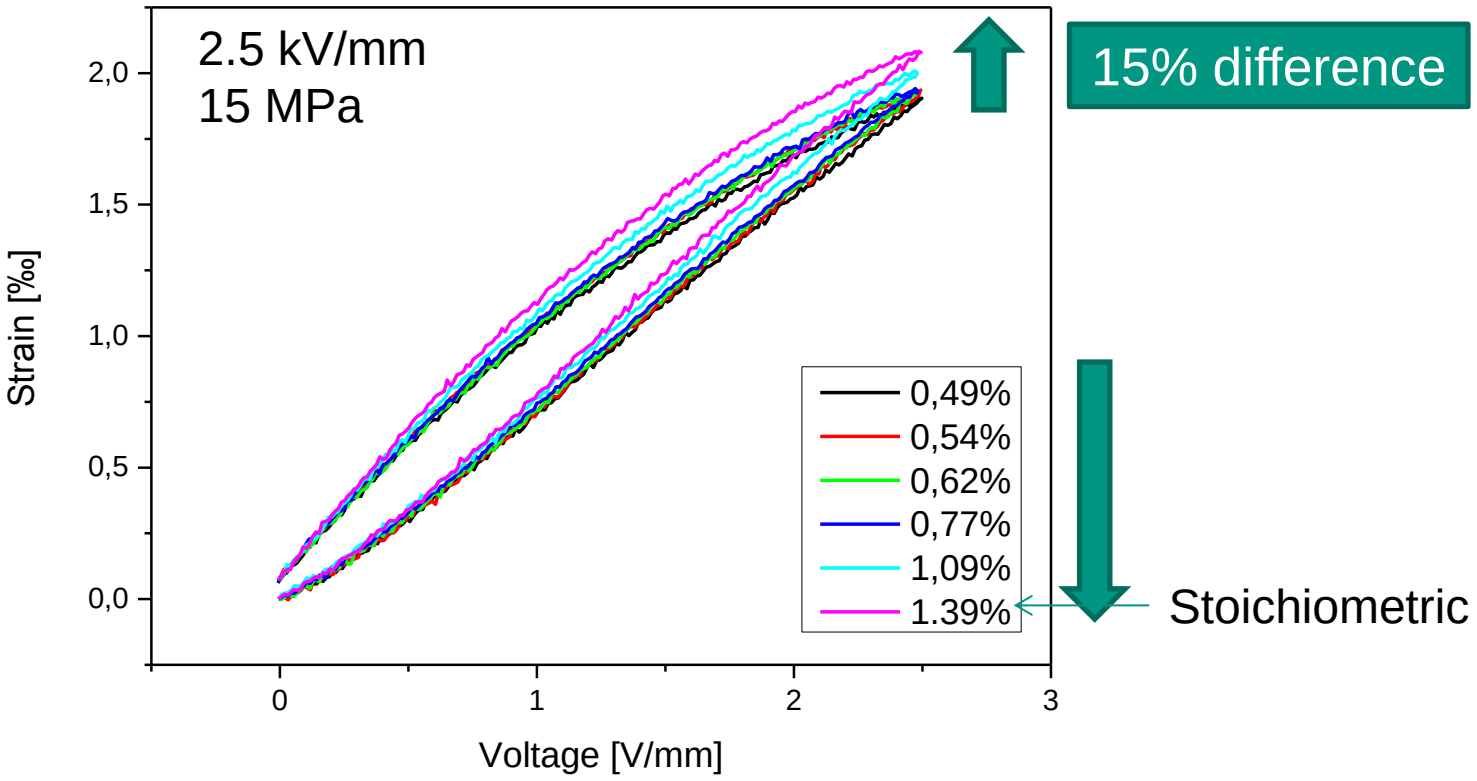


Sintering mass loss increases

Sintering Experiments with Actuators: Mass losses

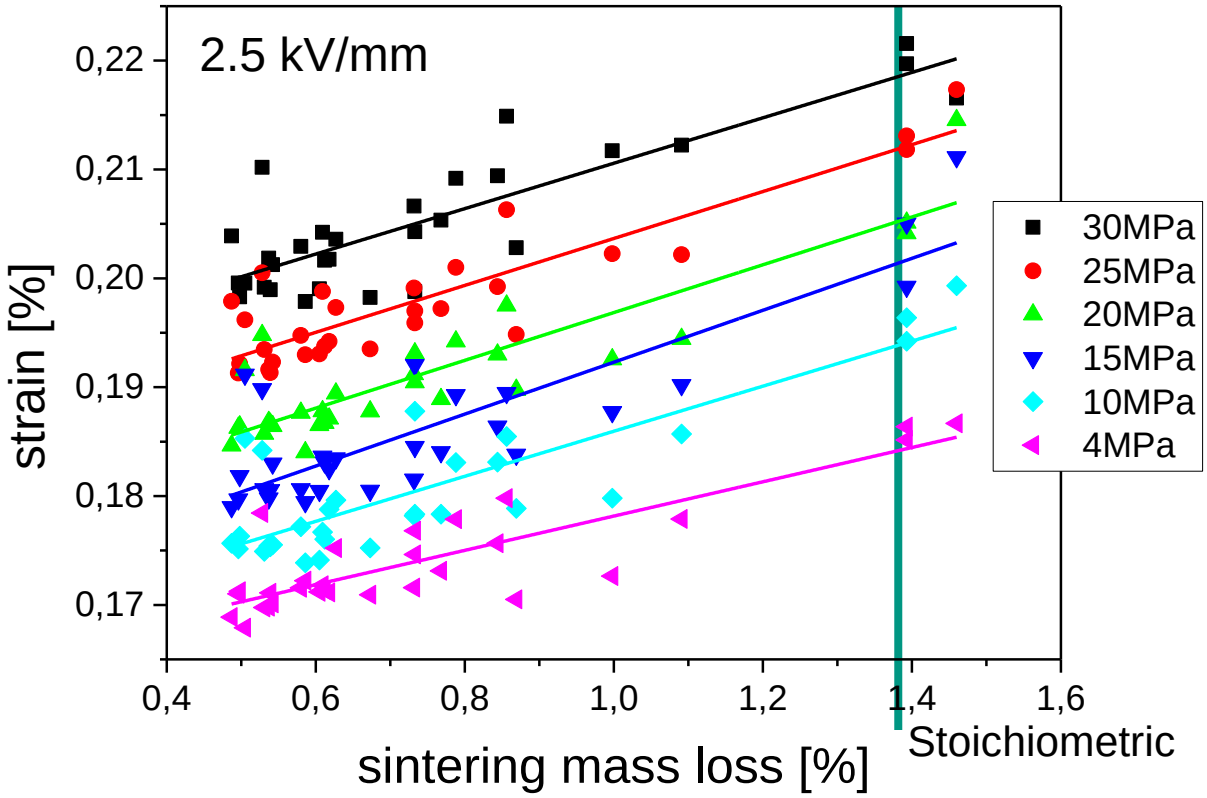


High field strain for different mass losses



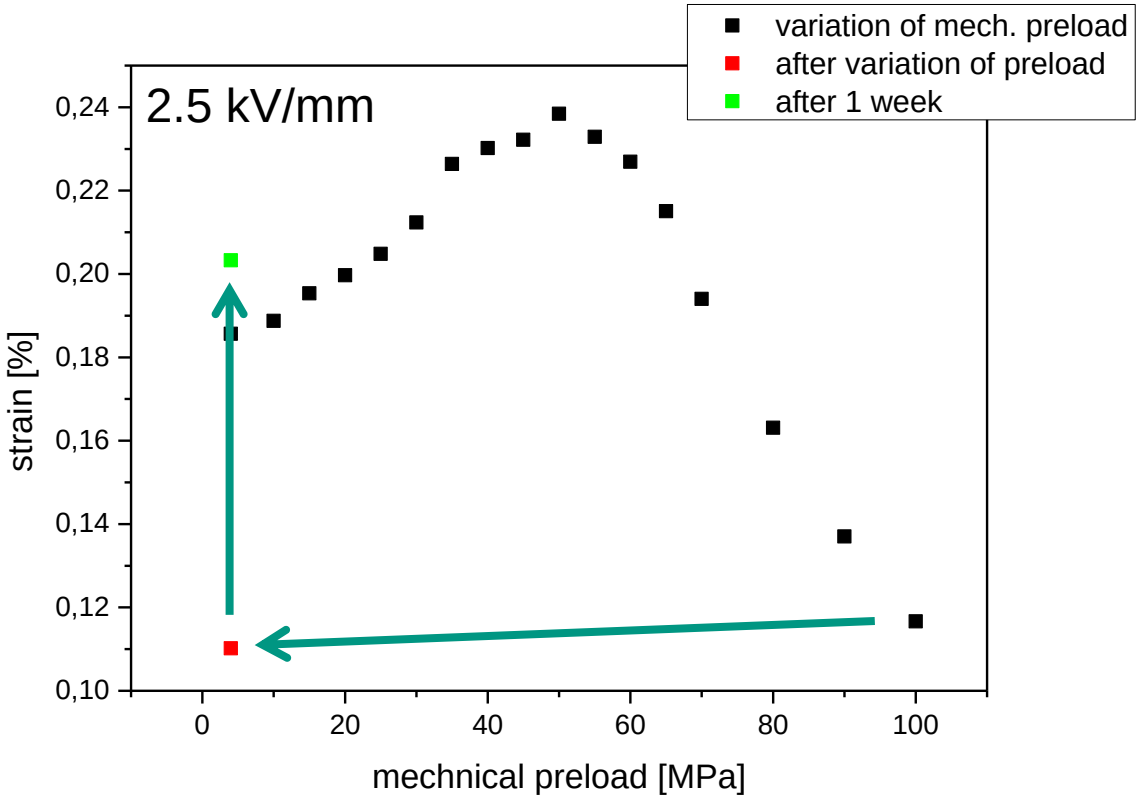
- Strong impact of the sintering mass loss on the high field strain
  - Highest strain for highest sintering mass loss

High field strain for different mass losses and preloads



- Strong impact of the sintering mass loss on the high field strain
  - Highest strain for highest sintering mass loss
- Strong influence of the mechanical preload
  - strain increases with mechanical preload

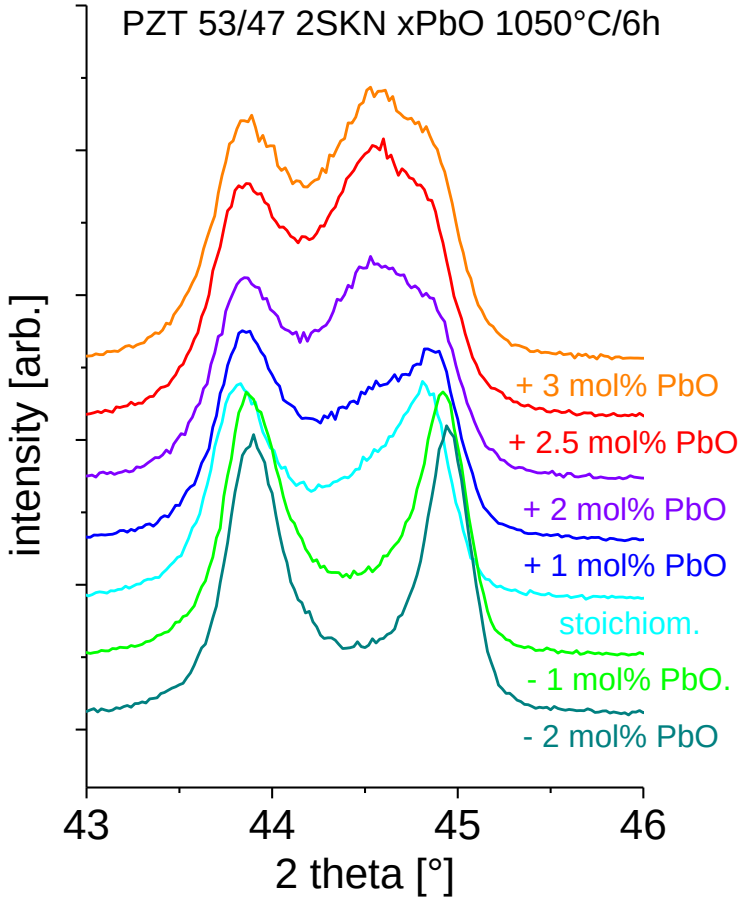
High field strain for different preloads

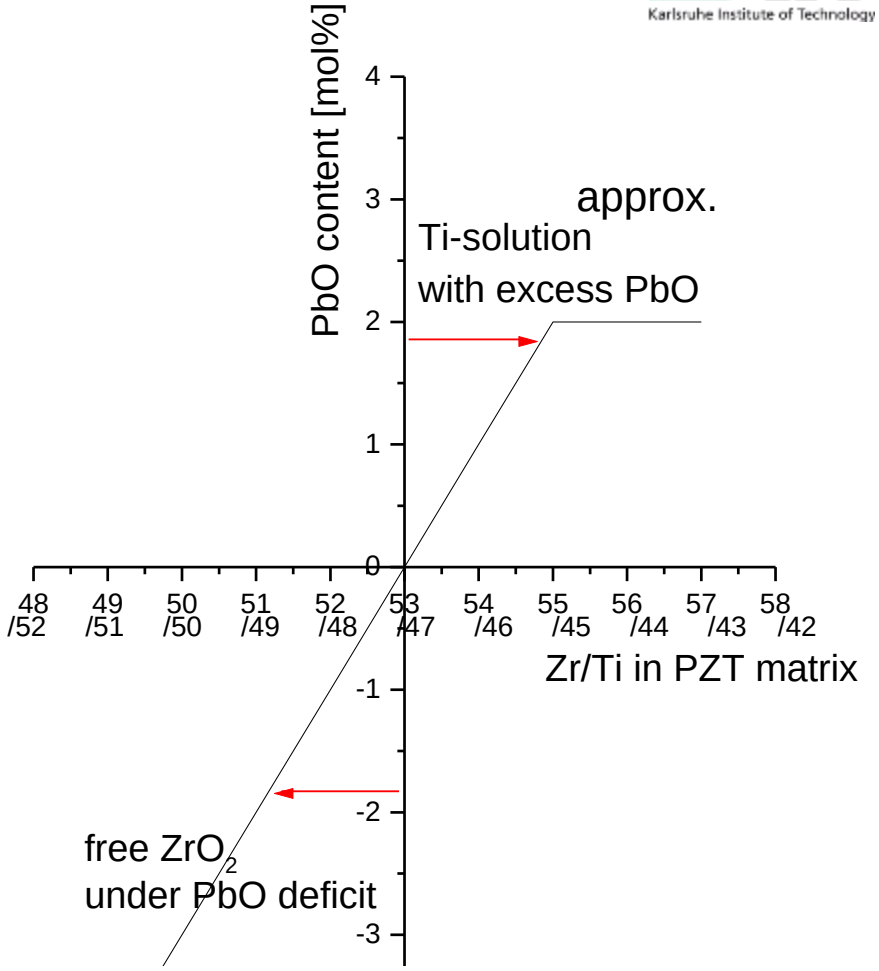


- Strong influence of the mechanical preload
  - Highest strain at 50 MPa
- Domain clamping effect?
- Domain creep?

- Comparison to bulk specimens

Shift in Chemical composition as origin of structural changes



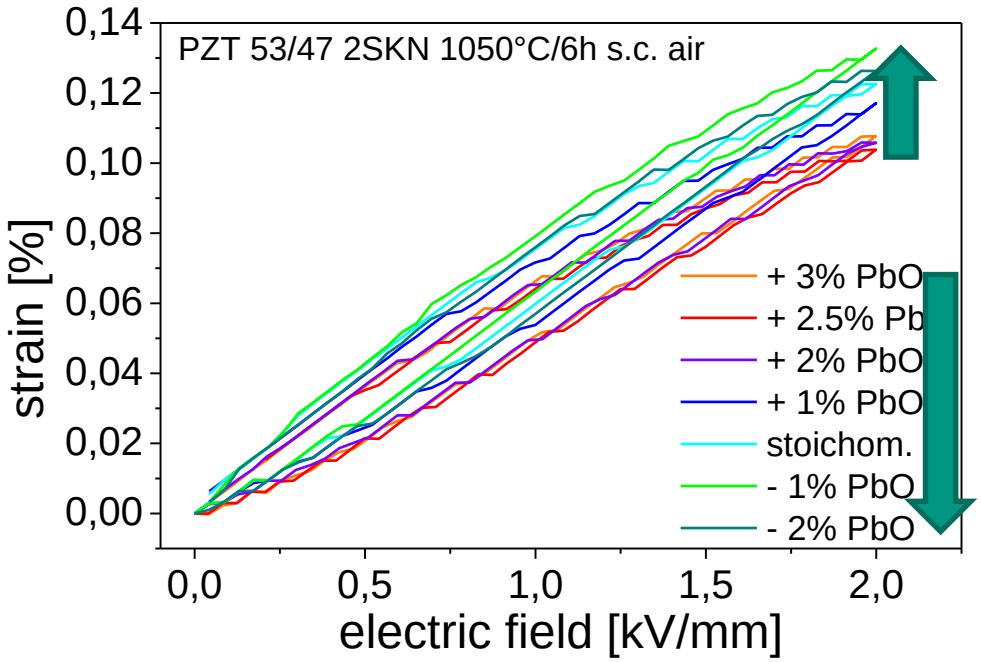


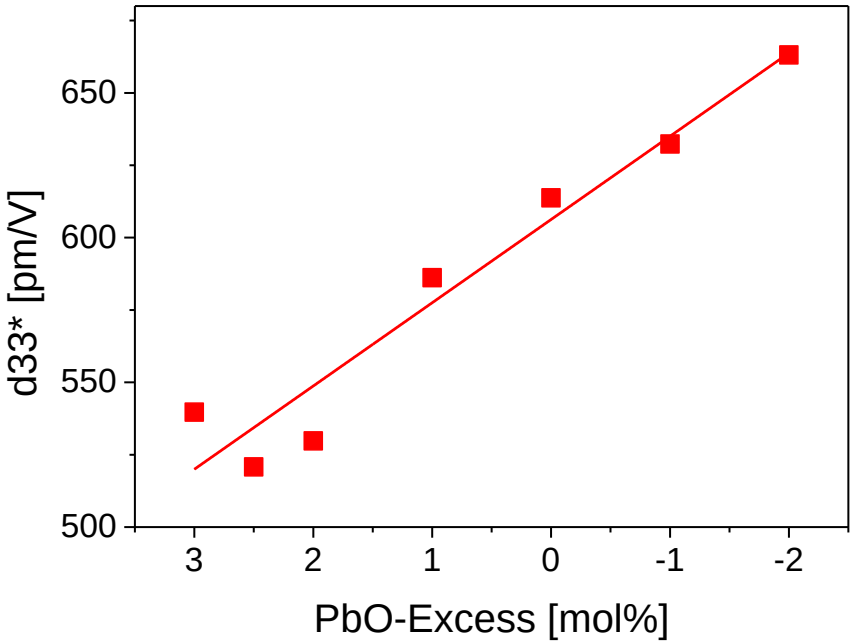
- Tetragonal fraction of the structure increases with reducing the PbO excess

- Change in Zr/Ti ratio of the PZT matrix
- Only up to 2 mol% PbO content

Effects of PbO content on strain under 2 kV/mm

>20% difference

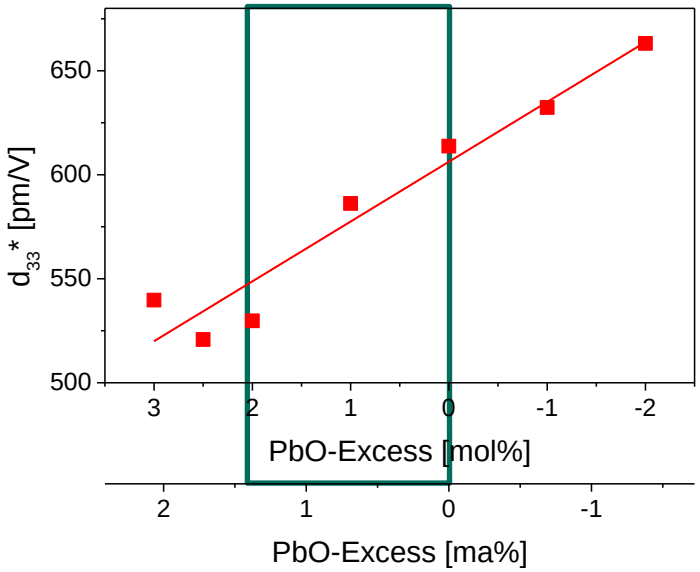




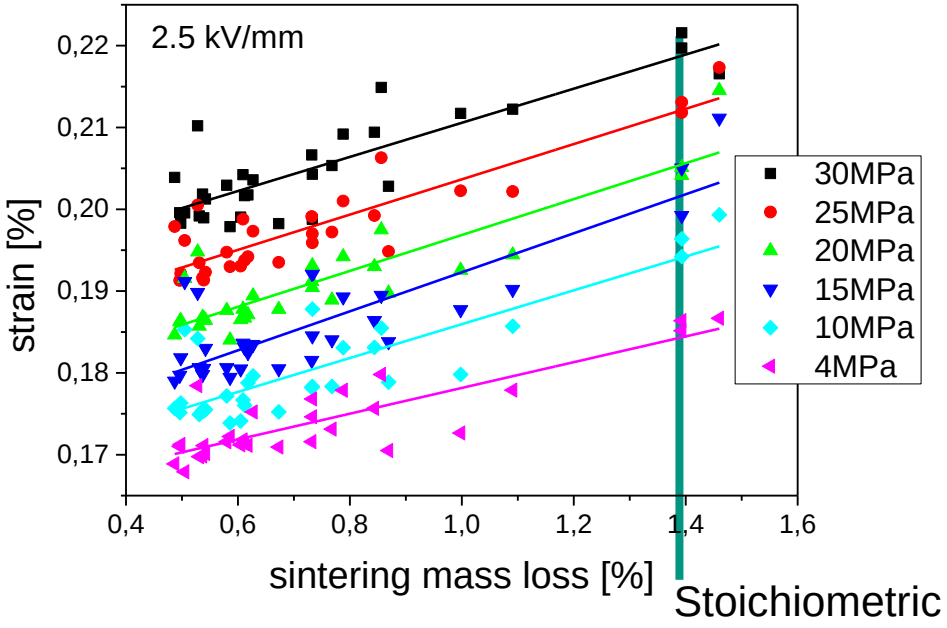
- Strong impact of the sintering mass loss on the high field strain
  - Highest strain for lowest PbO content
- For PbO excess >2mol% strain at 2kV/mm remains almost constant

High field strain: actuators and bulk specimens

Bulk specimen



Actuators



- Same behavior of actuators and bulk specimens

Summary

- Control of the PbO loss during sintering of multilayer actuators by special sintering setups is possible

- Stoichiometric (and PbO deficit) PZT gives
  - High strain
  - Low dielectric loss
  - Shift of the structure towards more tetragonal phase

  compared to PbO excess PZT

- Strong impact of the mechanical preload on the high field strain

- Both actuators and bulk specimen show the same behavior with a variation of the PbO content

Thanks for your attention!