SFB 595 A1

Deutsche Forschungsgemeinschaft

DFG

Manufacturing of Ceramic, Textured Actuators with High Strain

TECHNISCHE UNIVERSITÄT DARMSTADT

S-T. Zhang[1], A. Kounga[1], K. T. P. Seifert[1], R. Dittmer[1], M. Blömker[1], W. Jo[1], J. Rödel[1]

[1] Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Str. 2, 64287 Darmstadt, Germany

Motivation

- Environmental and health issues urge replacement of lead-containing piezoactuators
- $Bi_{1/2}Na_{1/2}TiO_3$-based solid solutions compete with PZT in terms of usable strain
- However: BNT-based systems are not as well understood as PZT and behave different in several respects
- Sound understanding of mechanisms will help designing novel actuator materials and further provide knowledge, applicable beyond the scope of actuators only

Objectives

- Elucidate nature of relevant phase transitions
- Characterize blocking stress (σ_b) as important figure of merit for actuators
  - At different temperatures
  - At varying electric fields
- Evaluation of actuator performance via maximum work output density *w*
- Influence of (co-)doping effected defect chemistry on piezoelectric properties

Result Highlights of Project A1

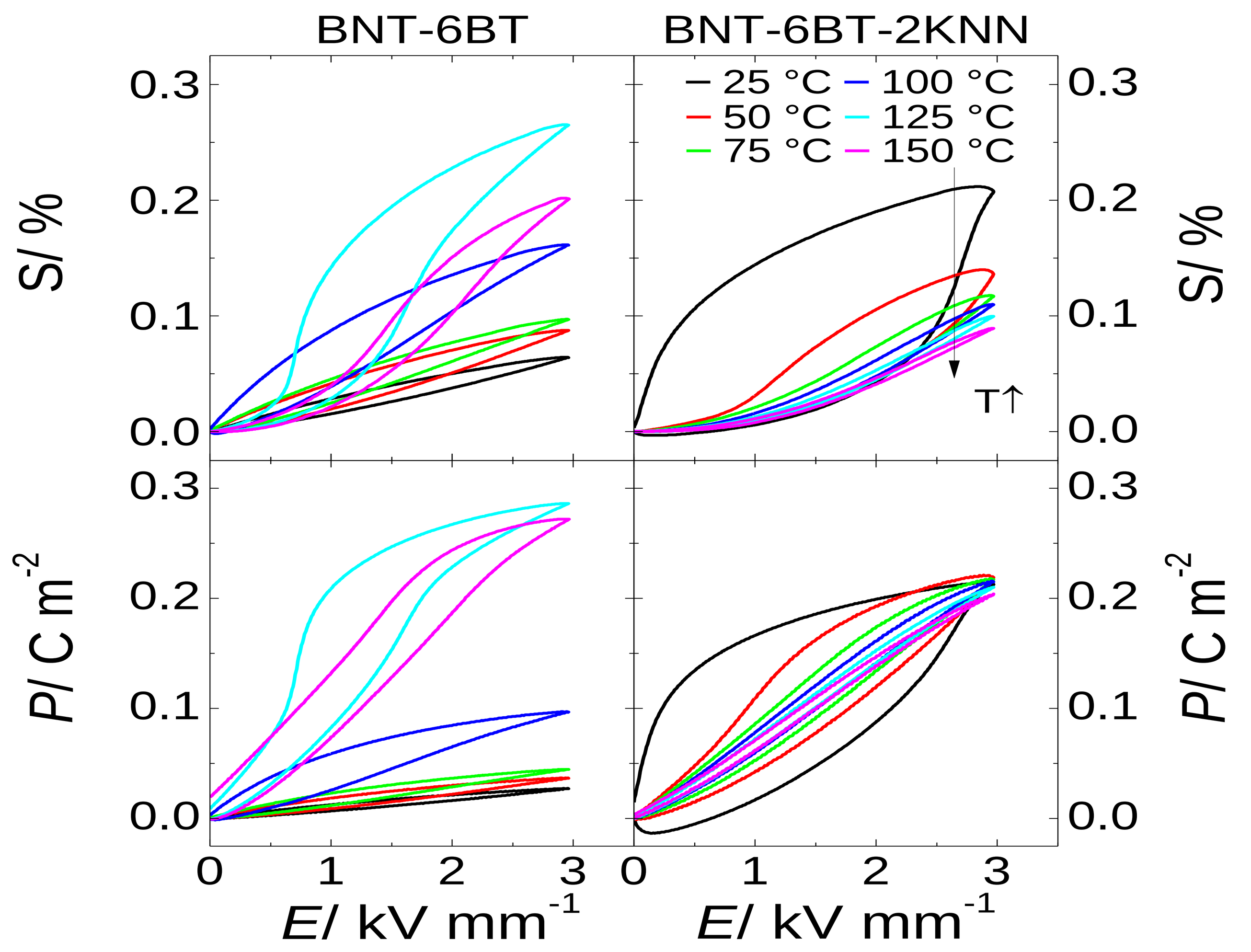

Figure 2 A giant strain was discovered for BNT-based materials (as for instance BNT-6BT or BNT6BT-2KNN), which also can be generated by adding other end-members such as BZT ($Bi_{1/2}Zn_{1/2}TiO_3$) or BMT ($Bi_{1/2}Mg_{1/2}TiO_3$) to the BNT system.

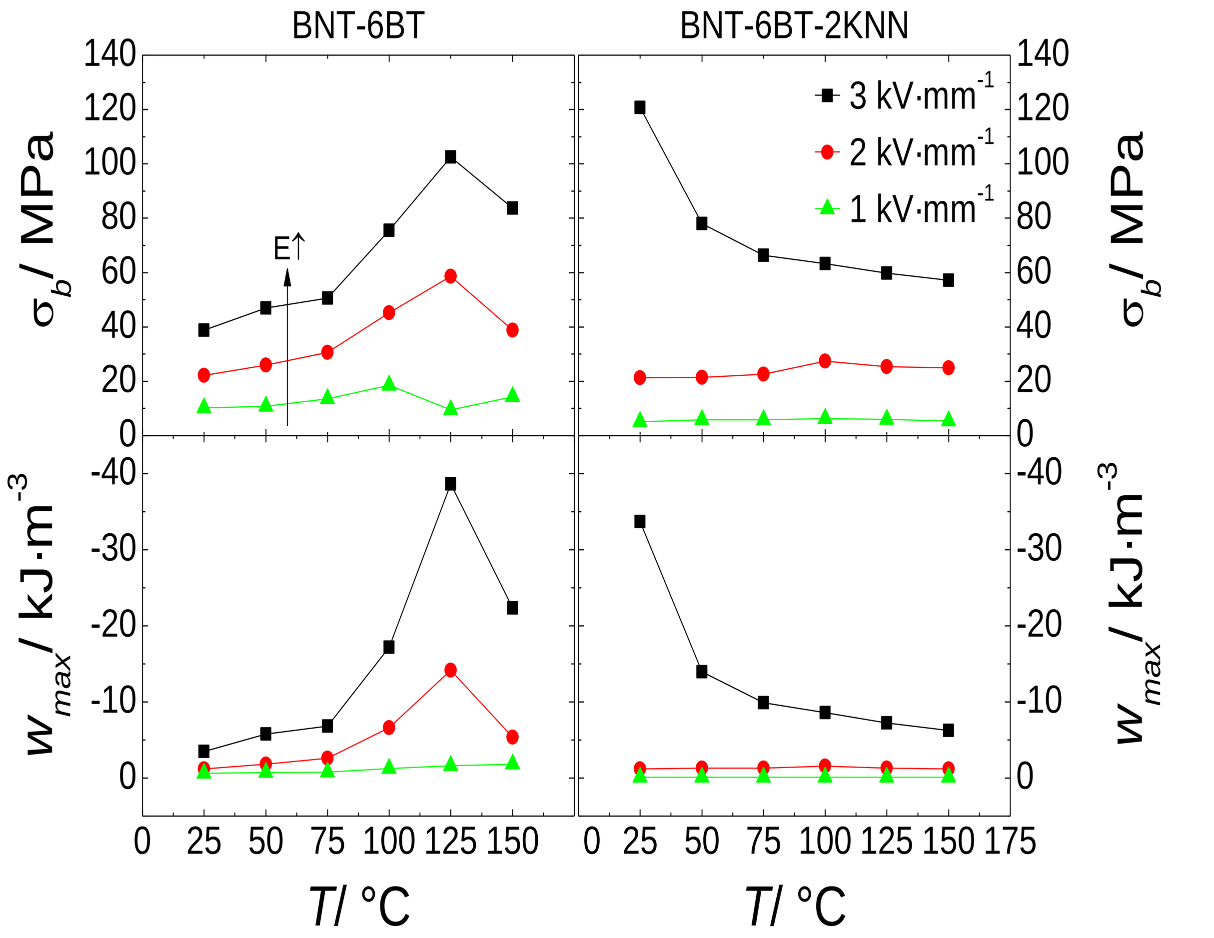

Figure 3 6BT provides 39 kJ/m³ of maximum work density at 125 °C. 2 mole% KNN shift optimum working temperature to 125 °C. (Dittmer *et al.*, Scr. Mater. **67**, (2012) 100-103)

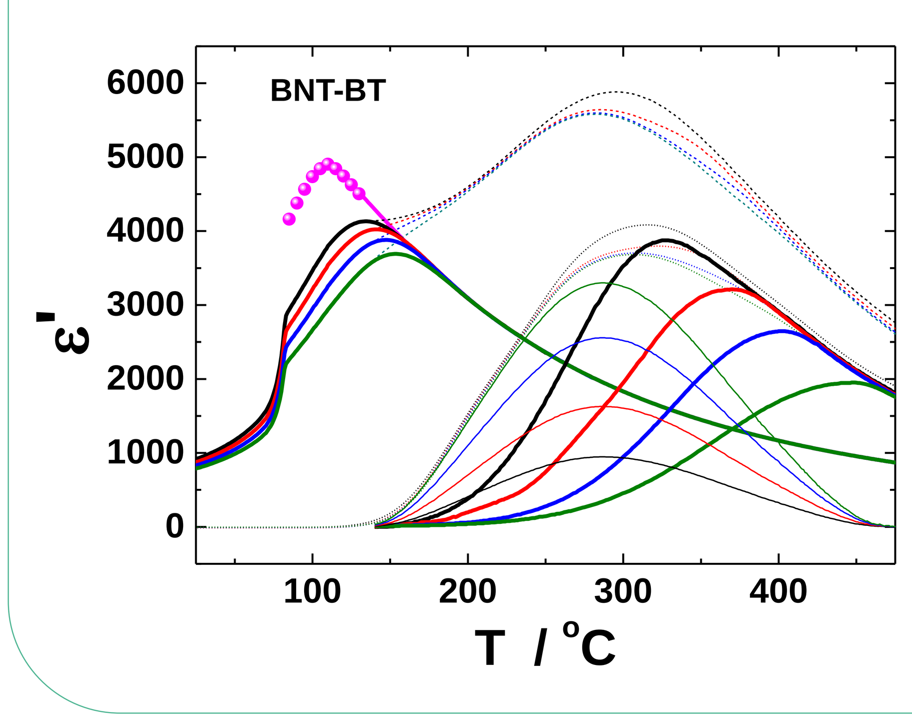

Figure 1 BNT-based materials were successfully evidenced as relaxor materials. (Jo *et al.*, J. Appl. Phys., **110** (2011) 074106)

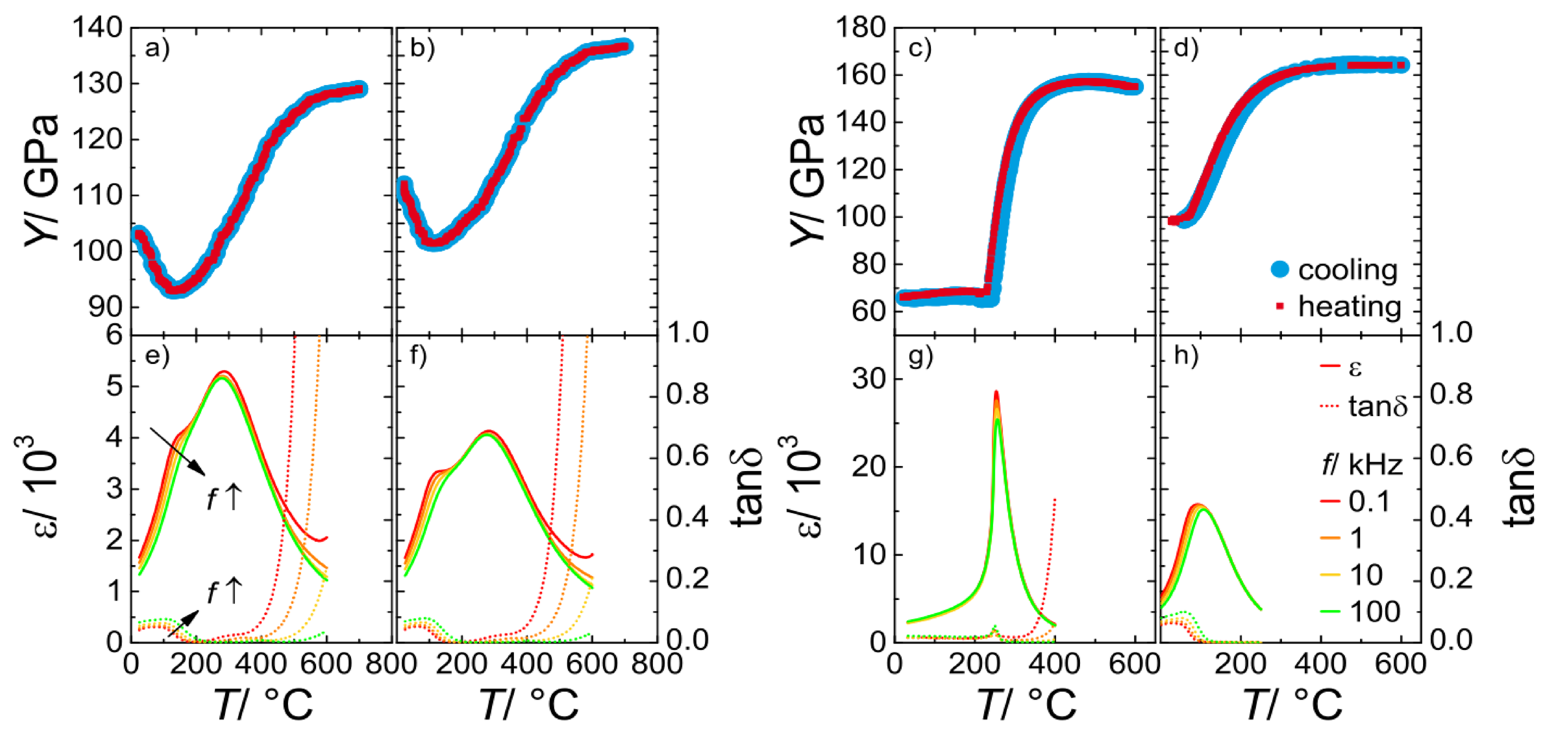

Figure 4 Young's modulus in addition to permittivity and loss tangent for (a) and (e) BNT-6BT, (b) and (f) BNT-6BT-2KNN, (c) and (g) soft PZT, and (d) and (h) PLZT 8/65/35. (Dittmer *et al.*, J. Appl. Phys. **115** (2014) 114109)

Conclusions

- BNT-based materials were characterized as relaxor materials (*c.f.* **Figure 2**)
- Giant strain for BNT-based materials was discovered (*c.f.* **Figure 1**) and results in a very high blocking stress
- Blocking stress exceeds lead based material (102 MPa at 125°C for BNT-6BT vs. 85 MPa for PZT; *c.f.* **Figure 3**)
- Structural changes, characteristic to BNT-based materials were identified by temperature-dependend Youngs modulus measurements (*c.f.* **Figure 4**)
- The generated broad scientific understanding of BNT-based materials can additionally be utilized in the fields of sensors, transducers, high-T dielectris or high-power applications

Current / Ongoing Work: Co-Doping in the BNT-BKT (BNKT) System

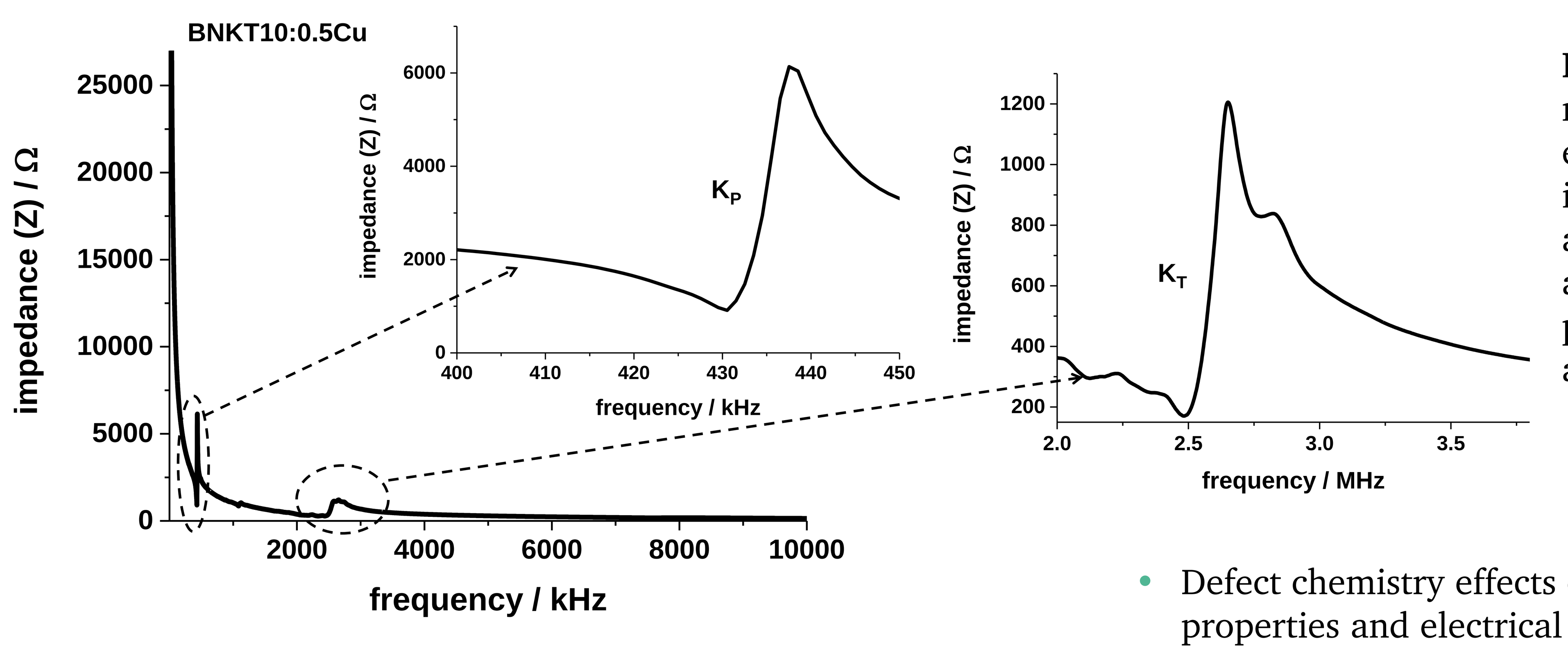

Figure 5 BNKT10 resonance response is especially pronounced in thickness mode (K_T) at about 2.5 – 3 MHz as compared to the planar mode (K_P) at about 420 - 450 KHz.

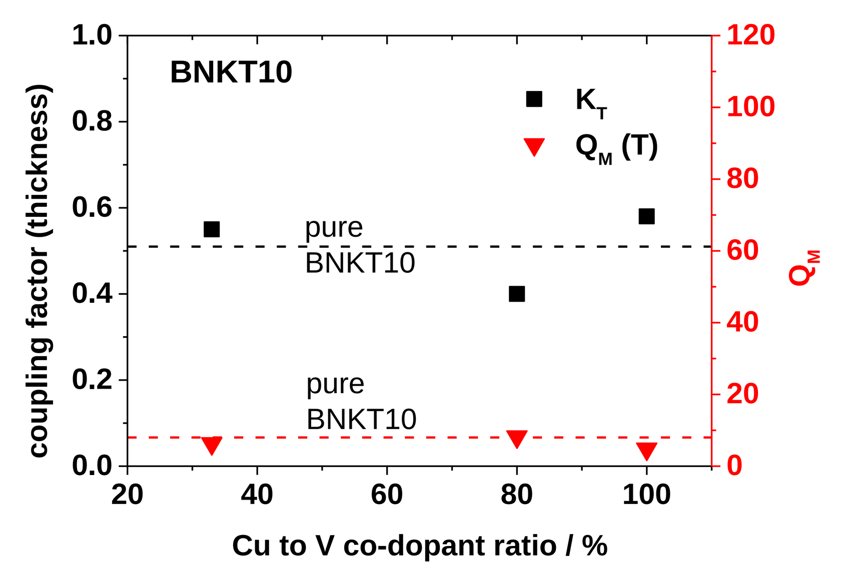

Figure 6 Dependence of the thickness mode coupling factor (K_T) and the respective mechanical quality factor (Q_M) of doped BNKT10 samples on the ratio of Cu to V co-dopant.

- Defect chemistry effects on piezoelectric properties and electrical properties
- EPR spectroscopy to characterize defects and their local surrounding
- Coupling factor (planar + thickness) determination according to IEEE standard
- K_T of BNKT10 with (co-)dopants is close to PZT (*c.f.* **Figure 6**) *e.g.* PIC151: K_T of 0.53