The Development of High Performance Actuator Material with Low Lead Content using the Spark-plasma-sintering Method

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Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
00 JUN 2003	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Development of High Performance Actuator Material with Low Lead Content using the Spark-plasma-sintering Method	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan; National Institute of Materials Science, Tsukuba, Japan; Tokyo Institute of Technology, Yokohama, Japan**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001697, ARO-44924.1-EG-CF, International Conference on Intelligent Materials (5th)(Smart Systems & Nanotechnology)., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**13**	

INTRODUCTION

Origin of colossal effects (e.g. colossal magnetoresistance in magnanites, colossal proximity effect in underdoped high temperature superconductors, giant dielectric constant in Pb-containing relaxor ferroelectrics):

intrinsic inhomogeneities

J. Burgy, M Mayr, V. Martin-Mayor, and E. Dagotto, Phys. Rev. Lett. 87, 277202(2001).

In $(Na_{0.5}K_{0.5})NbO_3$, the competing ferroelectric and antiferroelectric interactions coexist. By modifying its disorder with $PbTiO_3$, what will happen? Could the giant or colossal effect be possible?

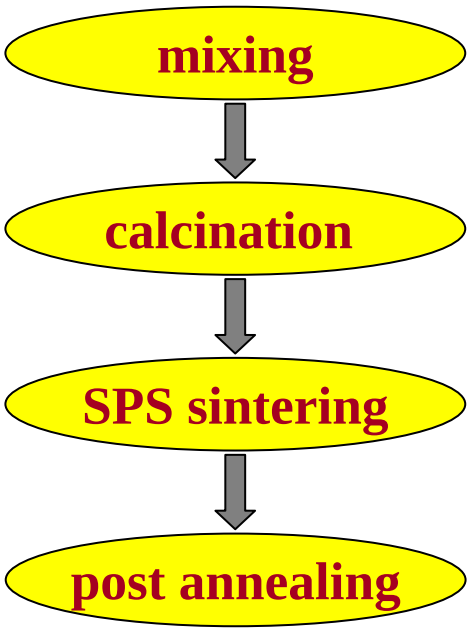
Objectives of the present research

- To characterize dielectric and piezoelectric properties of $(Na_{0.5}K_{0.5})NbO_3$-$PbTiO_3$ ceramics.

- To investigate the effect of random fields on performance of perovskite piezoelectrics.

EXPERIMENTAL

Sample preparation



Na_2CO_3, K_2CO_3, PbO, TiO_2, Nb_5O_2

950°C X 2hr, twice

1020 ~ 1100°C X 5 min

~ 60 MPa, vacuum

950°C X 5 hr, air

Measurements

- X-ray diffraction
- Scanning Electronic Microscopy
- Dielectric constant
- *DE*-loop
- Electromechanical coupling coefficient

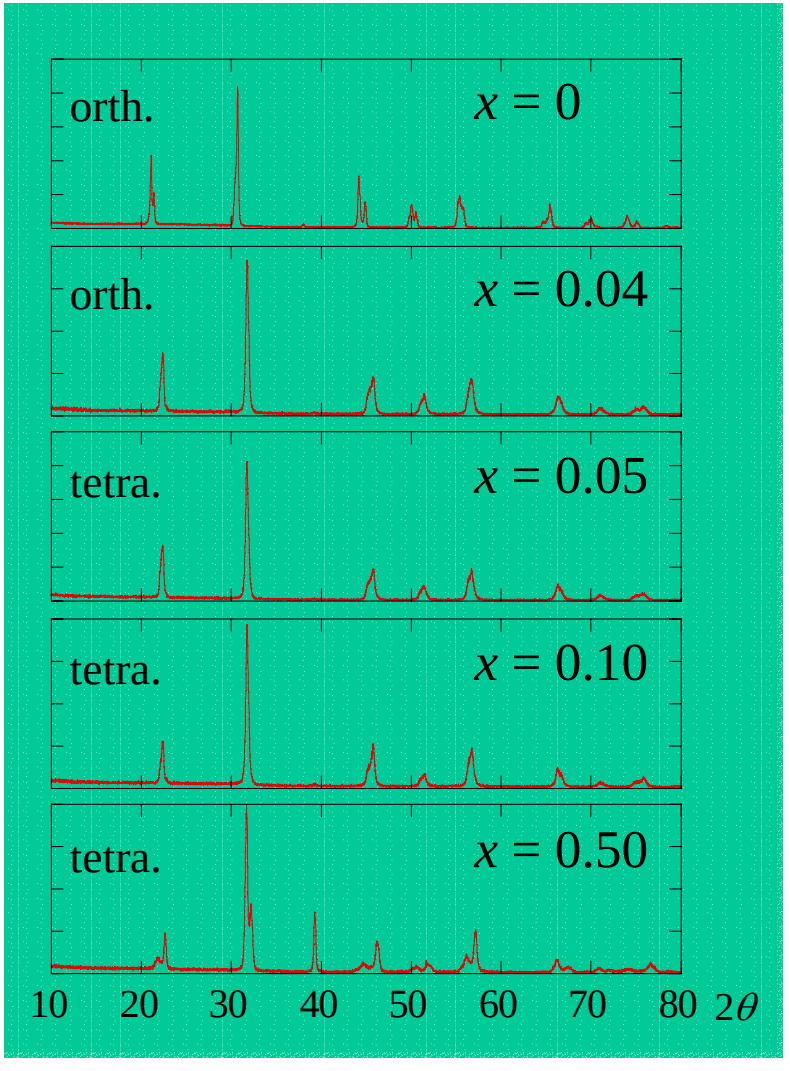
resonance method,

Sample sizes: ~5mmx5mmx0.5mm

poling conditions:

E ~30 kV/cmx15 mins, RT

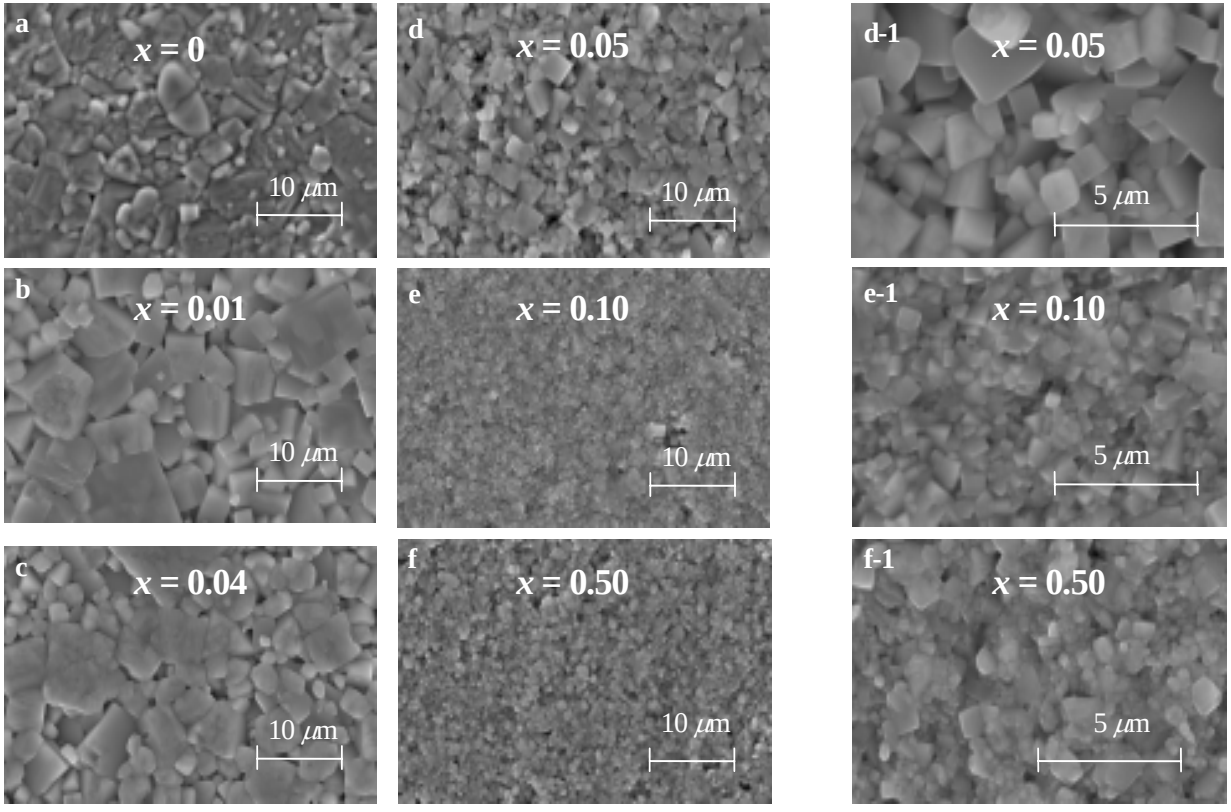
RESULTS


orth.
x = 0
orth.
x = 0.04
tetra.
x = 0.05
tetra.
x = 0.10
tetra.
x = 0.50
10
20
30
40
50
60
70
80
2θ

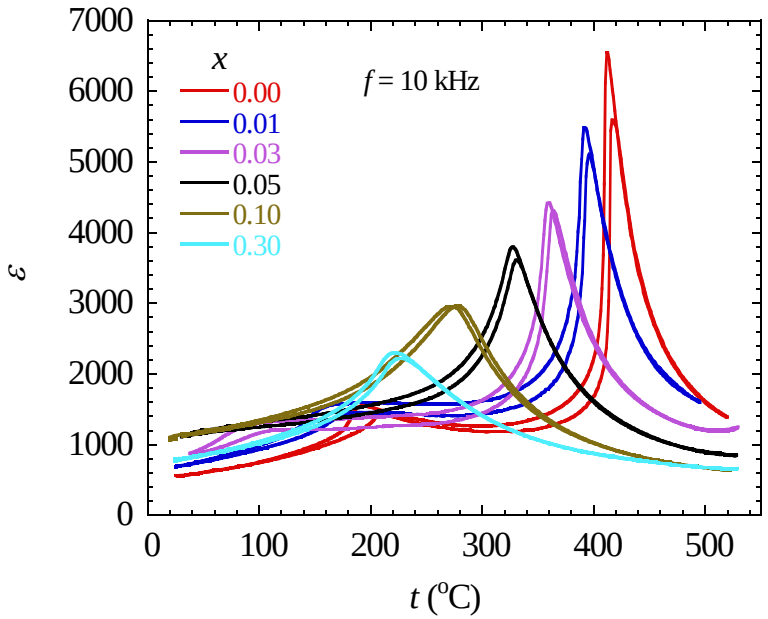
SEM images

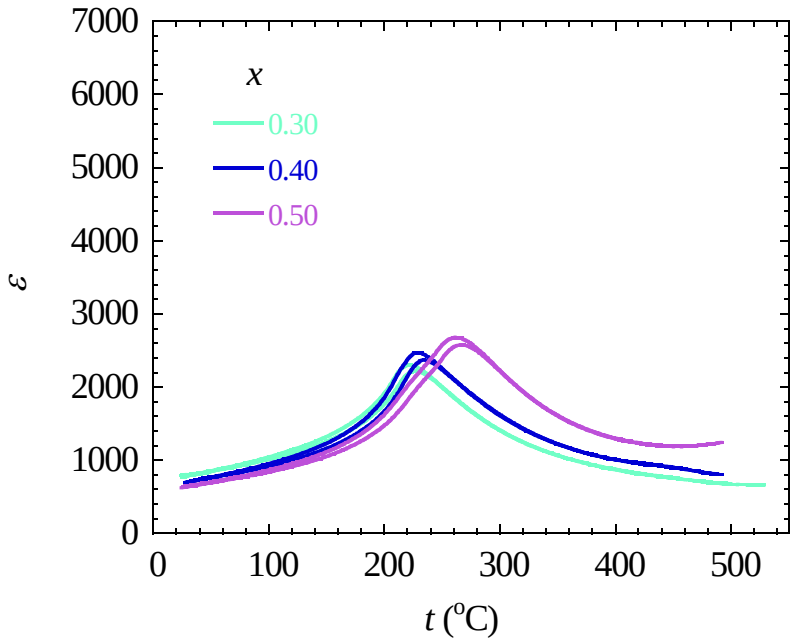
X 3000

X 10000

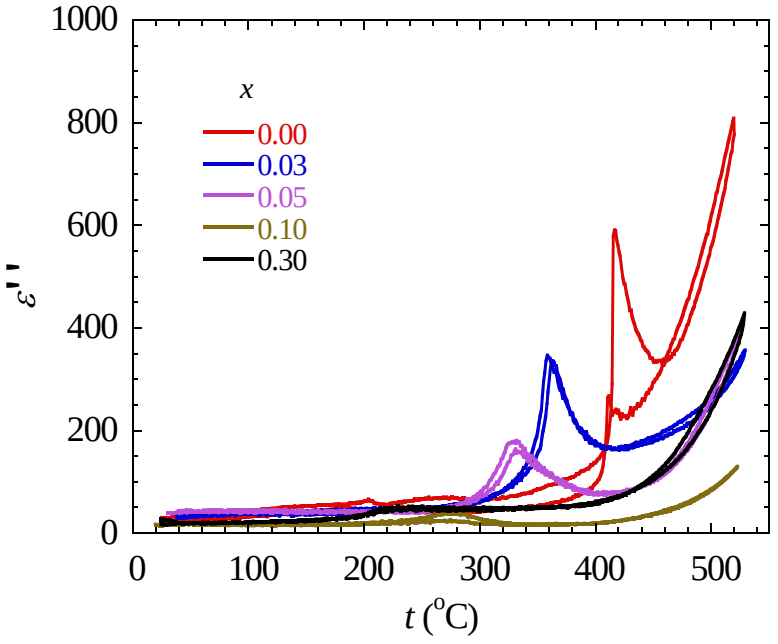


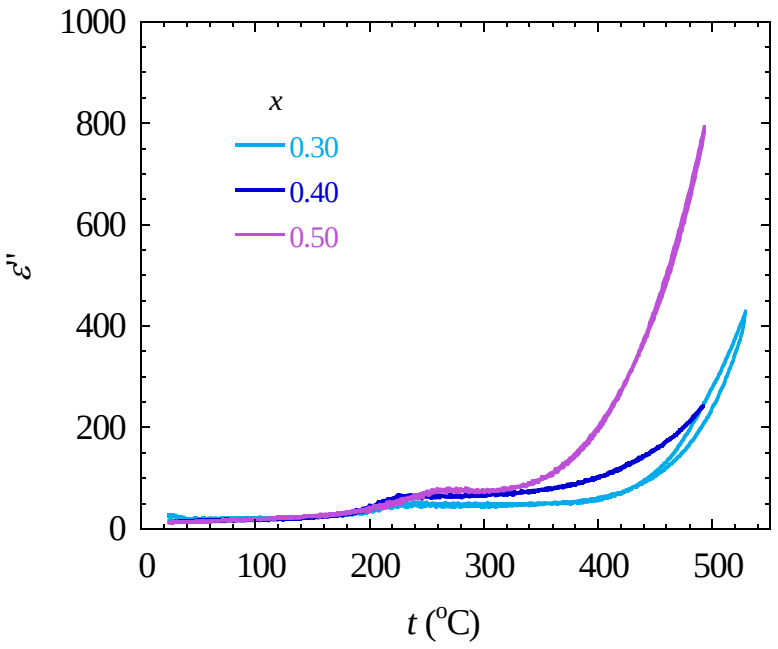
Real part of the dielectric constant



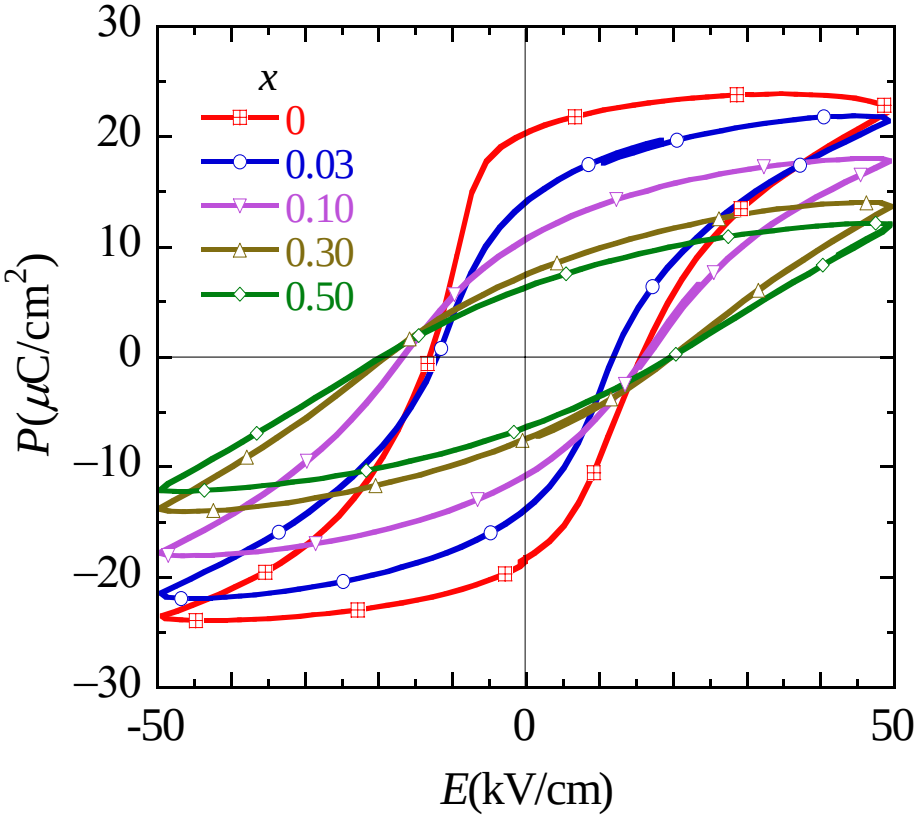


Imaginary part of the dielectric constant

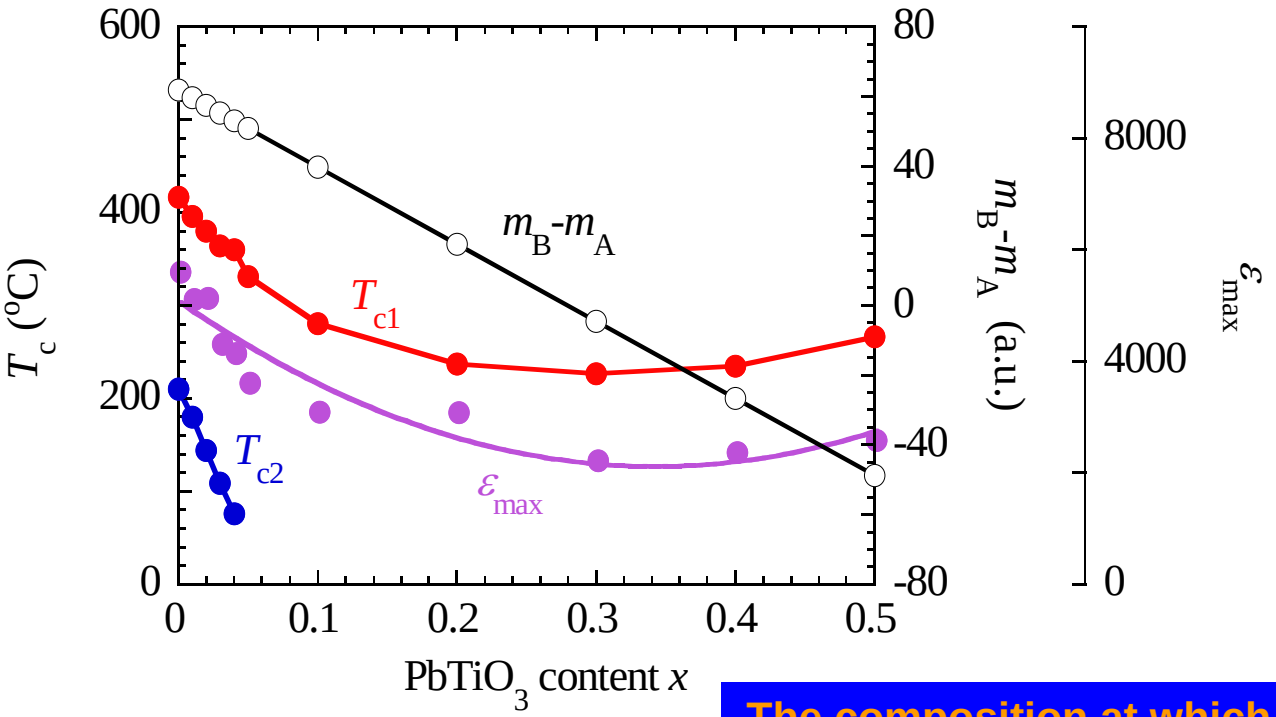




D vs. *E* loops



T_c, ε_{max}, and m_B-m_A vs. x



The composition at which m_B-m_A = 0 (x = 0.28) is very close to the composition where T_{c1} and ε_{max} show minimum (x = 0.30).

List of piezoelectric properties

$PbTiO_3$ content y	0	0.01	0.02	0.03	0.04	0.05	0.10	0.20	0.30	0.40	0.50
Relative density (%)	96.0	99.8	97.2	98.2	95.9	96.0	98.3	93.1	98.2	96.5	97.1
Remnant polarization ($\mu C/cm^2$)	19	21	19	14	15	15	11	11	8	8	6
Coercive field (kV/cm)	14	16	19	12	15	15	17	21	19	26	20
k_p (%)	18	26	21	25	22	24	16	12	13	10	10

SUMMARIES

- High density of $(1-x)(Na_{0.5}K_{0.5})NbO_3$-$xPbTiO_3$ ($x \leq 0.50$) samples were prepared by the SPS method.
- The improved electric field induced strain has been observed in the low *x* range. The modified domain structure is considered to be mainly responsible for the improvement.
- The dielectric properties tend to degrade with the intensification of the random fields.

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