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Short communication

Microstructure and electric properties of strontium niobate ceramics

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Abstract

Strontium niobate (SNO) ceramics were prepared by the conventional mixed-oxide method and the crystalline microstructure, surface morphology and electric properties were investigated. The X-ray diffraction pattern showed that there exists no other phases. The dielectric constant and dielectric loss were 54 and 1.3% at 10 kHz, respectively. The piezoelectric constant (d_{33}) reached 2.4 pC/N. There existed well-behaved hysteresis loops, and the remanent polarization (P_r) and the coercive field (E_C) of SNO ceramics are 0.022 μC/cm^2 and 3.56 kV/cm, respectively.

Keywords: Strontium niobate; Ceramics; Piezoelectric

1. Introduction

Piezoelectric materials have been applied to various devices such as piezoelectric transformers and ultrasonic motors [1–3]. With the development of science and technology, many industrials have expressed a real need for the capability of actuation and sensing at higher temperature [4]. When an operating temperature of above 750 °C is required, there is no suitable commercial piezoelectric material available [5]. The perovskite-like layer structure (PLS) ferroelectrics, such as $Sr_2Nb_2O_7$ (T_C = 1327 ± 5 °C), $Ca_2Nb_2O_7$ (T_C > 1525 °C), $Nd_2Ti_2O_7$ (T_C = 1482 ± 5 °C) and $La_2Ti_2O_7$ (T_C = 1461 ± 5 °C), can potentially operate above 1000 °C [5,6]. The PLS grain-oriented ceramics were prepared by spark plasma sintering (SPS) using a two-step method [5,6]. Among them, the piezoelectric constant (d_{33} = 2.8 ± 0.2 pC/N) of strontium niobate (short for SNO) is the largest one. The $Sr_2(Ta_{1-x}Nb_x)O_7$ ceramics were prepared by the flux method and dielectric properties were investigated [7].

In this paper, the SNO ceramics were prepared by the conventional mixed-oxide method and the crystalline microstructure, surface morphology and electric properties were investigated.

2. Experiments

2.1. Ceramics preparation

The starting chemicals were $SrCO_3$ (99.5% purity, Shanghai Jingchun company) and Nb_2O_5 (99.9% purity, Shanghai Guoyao group company) powders. SNO ceramics were prepared by the conventional mixed-oxide method. The raw material was weighed out in stoichiometric proportions, ball-milled in water, dried and then calcined at 1200 °C for 3 h. The obtained powders were pressed at 20 MPa into disks with a diameter of 10.0 mm and thickness of 1.5 mm prior to sintering at 1350 °C for 4 h.

2.2. Ceramics characterization

After sintering, X-ray diffraction (XRD, DX2700, China) with Cu Kα radiation (λ = 0.1541 nm) was performed to examine the phase constitution of the specimens at room temperature. Scanning electron microscopy (SEM, S3700, Hitachi, Japan) was used to investigate the morphology of SNO ceramics.

In order to measure the electric properties, silver paste was painted on the polished samples as the electrodes and fired at 830 °C for 15 min. The dielectric properties of the ceramics were determined with an Agilent E4980A LCR. The dielectric constant was calculated from the capacitance using the

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following equation:

$$\varepsilon = \frac{Cd}{\varepsilon_0 A} \quad (1)$$

where C is the capacitance (F), ε_0 the free space dielectric constant value (8.85×10^{-12} F/m), A the capacitor area (m^2) and d the thickness (m) of the ceramics. The piezoelectric constant was measured using a d_{33} meter (YE2730A, Institute of acoustics academic sinica, Beijing, China). The polarization–electric field (P–E) hysteresis characteristics were performed out using a TF2000 FE-HV ferroelectric test unit (aixACCT Inc., Germany).

3. Results and discussion

3.1. Crystalline structure

The X-ray diffraction pattern of SNO ceramics is shown in Fig. 1. The diffraction peaks match the indexed peaks for the SNO (JCPDS file no. 28-1246) structure parameters. No other phases are observed in the spectra. The lattice constants of SNO ceramics were calculated using MDI Jade 5.0 and a, b and c are, respectively, 0.39456 nm, 2.67346 nm and 0.56964 nm, which are appreciably smaller than that of PDF card (a = 0.39550 nm, b = 2.67800 nm, and c = 0.57010 nm).

3.2. Surface morphology

Fig. 2 shows the typical SEM micrographs of SNO ceramics. It is seen that the ceramics were very dense and crack-free. It is obvious that the grains are sheet but not spherical. The average grain size of the ceramics is 4–6 μm.

3.3. Electric properties

The frequency dependences of the dielectric constant and loss of SNO ceramics are shown in Fig. 3. It was found that as the frequency increases from 50 Hz to 200 kHz, both the dielectric constant and the dielectric loss firstly decrease and then increase. At 1 kHz, the dielectric constant and dielectric loss are 54.9 and 3.5%, respectively. However, the dielectric constant and dielectric loss decrease to 53.7 and 1.3% at 10 kHz, respectively. Comparing with SPS samples [6], the dielectric constant is slightly higher and the dielectric loss is almost equivalent.

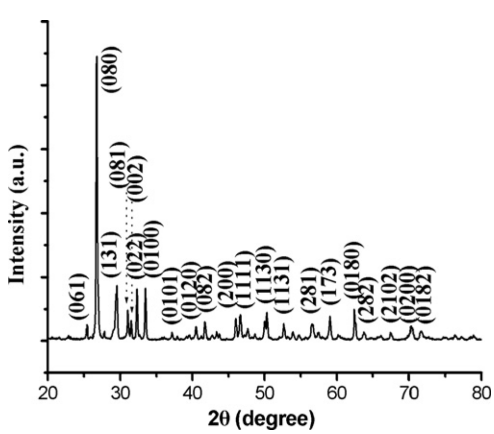

Fig. 1. XRD pattern of $Sr_2Nb_2O_7$ ceramics.

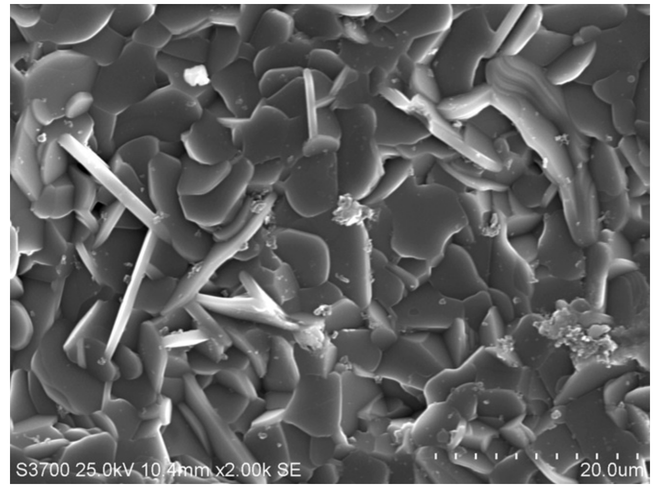

Fig. 2. Scanning electron micrograph of $Sr_2Nb_2O_7$ ceramics.

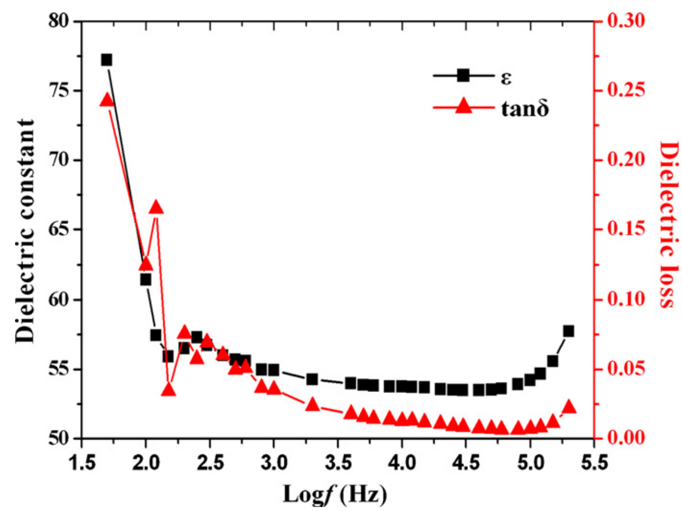

Fig. 3. Frequency dependences of the dielectric properties of SNO ceramics.

The piezoelectric constant d_{33} was measured by poling the samples in silicone oil at 300 °C under DC electric field of 10 kV/mm. The samples could not be poled under higher fields. The measured piezoelectric constant reached 2.4 pC/N, which is near to the value (2.8 pC/N) of SPS samples [6].

Fig. 4 shows the polarization hysteresis curves of the same ceramics at 1 kHz and 200 °C. It is found that well-behaved hysteresis loops can be observed. This suggests that at room temperature the crystal structures are in the ferroelectric phase, which is consistent with the XRD patterns. Moreover, it is found that the remanent polarization (P_r) and the coercive field (E_C) of SNO ceramics are 0.022 μC/cm² and 3.56 kV/cm, respectively, which are smaller than that of Ning's result due to lower electric field.

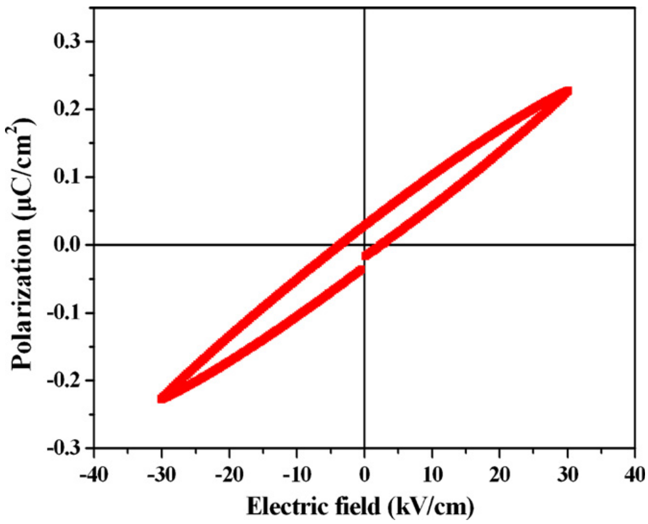

Fig. 4. Hysteresis loops for SNO ceramics at 1 kHz and 200 °C.

4. Conclusions

The crystalline microstructure, surface morphology and electric properties of strontium niobate (SNO) ceramics were investigated. The diffraction peaks match the indexed peaks for the SNO structure parameters. The grains are sheet and 4–6 μm. The dielectric constant and dielectric loss decrease to 54 and 1.3% at 10 kHz, respectively. The piezoelectric constant reached 2.4 pC/N. From the well-behaved hysteresis loops, it is found that the remanent polarization and the coercive field of SNO ceramics are 0.022 $\mu C/cm^2$ and 3.56 kV/cm, respectively.

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References

[1] E.A. Gurdal, S.O. Ural, H.Y. Park, S. Nahm, K. Uchino, High power $(Na_{0.5}K_{0.5})NbO_3$-based lead-free piezoelectric transformer, Jpn. J. Appl. Phys. 50 (2) (2011) 027101.

[2] D. Zhang, W. Ma, Q. Sun, H. Gao, Y. Zhang, The investigation of PMS–PNW–PZT piezoelectric ceramics, Ferroelectrics 403 (1) (2010) 134–141.

[3] J. Twiefel, T. Morita, Utilizing multilayer lithium niobate elements for ultrasonic actuators, Sens. Actuators A 166 (1) (2011) 78–82.

[4] Y. Wang, J. Wu, D. Xiao, W. Wu, B. Zhang, J. Zhu, P. Yu, L. Wu, High Curie temperature of (Li,K,Ag)-modified $(K_{0.50}Na_{0.50})NbO_3$ lead-free piezoelectric ceramics, J. Alloys Compd. 472 (1-2) (2009) L6–L8.

[5] H. Yan, H. Ning, Y. Kan, P. Wang, M.J. Reece, Piezoelectric ceramics with super-high Curie points, J. Am. Ceram. Soc. 92 (10) (2009) 2270–2275.

[6] H. Ning, H. Yan, M.J. Reece, Piezoelectric strontium niobate and calcium niobate ceramics with super-high Curie points, J. Am. Ceram. Soc. 93 (5) (2010) 1409–1413.

[7] H.D. Nam, Low temperature sintering and dielectric properties of $Sr_2(Ta_{1-x}Nb_x)O_7$ ceramics by the flux method, J. Kor. Inst. Electr. Electron. Mater. Eng. 8 (2) (1995) 158–163.