

煅烧温度对铌酸钾钠基铁电陶瓷压电性能的影响

王孟丽¹, 桑秀杰¹, 周 静¹, 李 芳¹, 李 敏²

(1. 潍坊职业学院, 山东 潍坊 262737; 2. 池州学院, 安徽 池州 247000)

摘 要: 铁电陶瓷在电场下产生应变性能, 是制备致动器的关键元件。多相共存结构的铁电陶瓷产生大应变, 除了组成, 混合料煅烧条件影响相结构和应变性能。采用传统固相烧结法制备 0.97KNNs-0.03BNKZ ($0.97(\text{K}_{0.48}\text{Na}_{0.52})(\text{Nb}_{0.97}\text{Sb}_{0.03})\text{O}_3-0.03\text{Bi}_{0.5}(\text{K}_{0.48}\text{Na}_{0.52})_{0.5}\text{ZrO}_3$) 铁电陶瓷, 研究混合料煅烧温度在 600~950 °C 范围内对陶瓷的直径收缩率、微观形貌、晶体结构、介电性能、铁电性能和应变性能的影响。结果表明, 随混合料煅烧温度的增加, 陶瓷直径收缩率先增加至 8.5% 然后减小; 陶瓷平均晶粒尺寸先减小后增加至 0.48 μm ; 所有陶瓷晶体具有畸变的正交结构; Curie 温度从 280 °C 增加到 320 °C, 相应地最大介电常数从 4 520 增加到 7 769; 最大极化强度先减小后增加, 最高达到 35 $\mu\text{C}/\text{cm}^2$ 。煅烧温度为 950 °C 时, 陶瓷在 40 kV/cm 电场下其双极应变达到 0.3%, 原因在于铁电畴易翻转; 其它煅烧温度制备的陶瓷其应变性能在 0.25% 左右, 区别不大。

关键词: 煅烧; 铌酸钾钠陶瓷; 压电性能

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铁电陶瓷在电场作用下利用逆压电效应、铁电畴翻转等产生应变, 是制备致动器的关键元件^[1]。无铅铁电陶瓷目前被广泛应用, 但其高铅含量对人体和环境有害, 无铅铌酸钾钠($\text{K}_{1-x}\text{Na}_x$) NbO_3 基陶瓷期望能替代铅基陶瓷。陶瓷相结构是影响其应变性能的因素之一, 室温下具有多相共存结构的($\text{K}_{1-x}\text{Na}_x$) NbO_3 基陶瓷, 增加可能的极化方向, 进而增加陶瓷应变性能^[2]。例如, Kong 等^[3]制备的 $(1-x)(\text{K}_{0.52}\text{Na}_{0.48})(\text{Nb}_{0.95}\text{Sb}_{0.05})\text{O}_3-x\text{CaZrO}_3$ ($x=0.02$) 陶瓷, 具有 R-T 两相共存结构, 在 35 kV/cm 电场下诱导应变 0.23%。Zheng 等^[4]制备的 $0.96(\text{K}_{0.48}\text{Na}_{0.52})(\text{Nb}_{0.95}\text{Sb}_{0.05})\text{O}_3-0.04(\text{Bi}_{0.5}\text{M}_{0.5})\text{ZrO}_3$ 陶瓷, 具有 R-T 两相共存结构, 在 30 kV/cm 电场下诱导应变 0.46%, 但应变迟滞非常大。Wang 等^[5]设计 $(1-x)(\text{K}_{1-y}\text{Na}_y)(\text{Nb}_{1-z}\text{Sb}_z)\text{O}_3-x\text{Bi}_{0.5}(\text{Na}_{1-w}\text{K}_w)_{0.5}\text{ZrO}_3$ ($0\leq x\leq 0.05$, $0.40\leq y\leq 0.68$, $0\leq z\leq 0.08$, $0\leq w\leq 1$) 体系, 调节组成可使陶瓷具有不同的相结构, 当 $0.02\leq x\leq 0.035$ 时, 陶瓷具有 R-O-T 三相共存结构, 增加陶瓷压电性能; 这个体系在陶瓷中构建不同相共存结构时, 需要精细调控组成和工艺, 尤其是预

烧工艺。

预烧就是将各种原料在一定温度下进行固相反应, 目的是将原料合成目标组分的晶体结构且没有原料成分。预烧后粉体的活性、颗粒尺寸、均匀性对生坯烧结难易程度和陶瓷电学性能有很大影响^[6]。Wu 等^[7]发现煅烧温度影响 $0.96(\text{K}_{0.5}\text{Na}_{0.5})(\text{Nb}_{0.96}\text{Sb}_{0.04})\text{O}_3-0.04\text{Bi}_{0.5}(\text{Na}_{0.5}\text{K}_{0.5})_{0.5}\text{ZrO}_3$ 的陶瓷, 随原料煅烧温度增加, 陶瓷晶粒尺寸逐渐增大; 原料在 500 °C 煅烧, 陶瓷获得 R-O-T 三相共存结构, 而原料在 650~950 °C 煅烧, 陶瓷获得 R-T 两相共存结构, 其中原料在 850 °C 条件下煅烧, 陶瓷获得最佳的压电性能; 没有报道煅烧温度对陶瓷应变性能的影响。

($\text{K}_{1-x}\text{Na}_x$) NbO_3 基陶瓷中 K 与 Na 比例为 0.48:0.52 时^[8-9], 陶瓷具有单斜的 M 和正交的 O 两相共存, 类似准同型相界的作用, 使陶瓷具有较高的压电常数为 160 pC/N, 所以本工作选择 $\text{K}_{0.48}\text{Na}_{0.52}\text{NbO}_3$ 为基体, $\text{Bi}_{0.5}(\text{K}_{0.48}\text{Na}_{0.52})_{0.5}\text{ZrO}_3$ 为掺杂剂, 设计体系 $0.97(\text{K}_{0.48}\text{Na}_{0.52})(\text{Nb}_{0.97}\text{Sb}_{0.03})\text{O}_3-0.03\text{Bi}_{0.5}(\text{K}_{0.48}\text{Na}_{0.52})_{0.5}\text{ZrO}_3$ (简称 0.97KNNs-0.03 BNKZ)。通过调节煅烧温度, 有助于构建多相共存的 KNN 基陶瓷提高其应变性

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第一作者: 王孟丽(1984—), 女, 硕士, 讲师。

通信作者: 李 敏(1983—), 女, 硕士, 副教授。

Received date: 2023-09-18. Revised date: 2024-01-04.

First author: WANG Mengli (1984—), female, Master, Lecturer.

E-mail: 13516362561@163.com

Correspondent author: LI Min (1983—), female, Master, Associate Professor.

E-mail: 714821655@qq.com

能。研究煅烧温度对 0.97KNNS–0.03BNKZ 铁电陶瓷致密性、相结构、介电性能、铁电性能、应变性能的影响,旨在制备高应变性能的陶瓷。

1 实验

1.1 样品制备

以传统固相烧结法制备 0.97KNNS–0.03BNKZ 铁电陶瓷。首先按照化学式进行配料,将各种原料加入球磨罐中,按照料、球、水质量比为 1:2:2 的比例,再加入氧化锆珠子和无水乙醇继续加入球磨罐中。再将其在球磨机中球磨 12 h 后,将浆料烘干、过筛。然后称 20.0 g 0.97KNNS–0.03BNKZ 组分的混合料置于坩埚中,将其在 600~950 °C 之间保温 3 h 进行煅烧。预烧料经球磨、烘干后,在其中加入质量分数 0.1% 的聚乙烯醇缩丁醛进行造粒,将造粒料采用单压成型,压成直径为 13 mm 的生坯。将生坯放在氧化铝承烧台上,生坯上下表面用相同组分的煅烧料掩埋,用氧化铝坩埚盖上,再用氧化铝粉密封,最后将其放入高温炉中以 5 °C/min 分别升温至 1 180 °C 保温 3 h 后,随炉冷却获得陶瓷样品。

1.2 样品表征

样品直接清洗烘干后进行测试。用 SmartLab 3 kW 扫描电子显微镜测试陶瓷表面晶粒形貌,测试条件:电压 15 kV。Archimedes 排水法测试陶瓷密度 ρ [见式(1)]。陶瓷直径收缩率 l 测试见式(2)。陶瓷相对密度 A 测试见式(3)。

$$\rho = (m_1 \times \rho_0) / (m_2 - m_3) \quad (1)$$

$$l = (D_1 - D_0) / D_1 \quad (2)$$

$$A = \rho / \rho_t \quad (3)$$

其中: m_1 为陶瓷干重, ρ_0 为水的密度, m_2 为陶瓷湿重, m_3 为陶瓷悬重; D_1 为陶瓷生坯直径; D_0 为烧结后陶瓷直径; ρ_t 为陶瓷理论密度。采用 Precision Premier II 型铁电系统获得陶瓷铁电和应变性能,测试条件:室温下,频率 10 Hz。采用 X 射线衍射测试陶瓷物相结构,测试条件: Cu 靶,管电压 40 kV,管电流 30 mA。采用 TZDM 型介电仪器分析陶瓷介电性能,测试条件:频率 10 Hz,室温至 400 °C。

2 结果与讨论

将不同温度制备的煅烧料压成生坯,在最佳烧结温度 1 180 °C 保温 3 h,陶瓷的直径收缩率和密度如表 1 所示。由表 1 可知,随煅烧温度增加,0.97KNNS–0.03BNKZ 陶瓷的直径收缩率和密度分别先增加后减小。煅烧温度小于等于 700 °C 时,陶

瓷密度从 4.22 g/cm³ 增加到 4.42 g/cm³,相对密度从 80.3% 增加到 89.1%,直径收缩率从 4.5% 增加至 6.6%,整体致密性依然很低。当煅烧温度在 750~900 °C 时,陶瓷密度、直径收缩率和相对密度分别为 4.4 g/cm³、8.5% 和 94% 左右;煅烧温度为 800 °C 时,陶瓷致密性最高;当煅烧温度为 950 °C 时,陶瓷密度、直径收缩率和相对密度分别为 7.5%、4.38 g/cm³ 和 80.5%,陶瓷致密性明显下降。煅烧温度低于 700 °C 和高于 950 °C 时,陶瓷致密性低;煅烧温度在 800 °C 时,陶瓷致密性最高。

表 1 不同煅烧温度保温 3 h 和 1 180 °C 保温 3 h 制备 0.97KNNS–0.03BNKZ 铁电陶瓷的直径、收缩率、密度和相对密度

Table 1 Diameter, shrinkage rate, density and relative density of 0.97KNNS–0.03BNKZ ferroelectric ceramics sintered at 1 180 °C for 3 h at different calcination temperature for 3 h

Calcination temperature/°C	Diameter/mm	Shrinkage rate/%	Density/(g·cm ⁻³)	Relative density/%
600	12.42	4.5	4.21	80.3
650	12.26	5.7	4.22	86.4
700	12.14	6.6	4.42	89.1
750	11.90	8.5	4.42	93.9
800	11.90	8.5	4.42	94.9
850	11.90	8.5	4.41	93.4
900	11.86	8.5	4.45	89.1
950	12.02	7.5	4.38	80.5

图 1 为混合料在不同煅烧温度下保温 3 h, 0.97KNNS–0.03BNKZ 生坯在 1 180 °C 保温 3 h 制备的陶瓷其微观形貌图。由图 1 可见:温度为 600 °C 时,陶瓷具有异常长大的晶粒,这是由于混合料活性高;1 180 °C 的温度就偏高导致晶粒异常长大;煅烧温度在 650~850 °C 之间,陶瓷晶粒比较均匀;煅烧温度在 900~950 °C 之间,陶瓷晶粒尺寸稍微增大且结合不紧密。所有陶瓷的晶粒是块状且存在气孔,随煅烧温度的增加,0.97KNNS–0.03BNKZ 陶瓷晶粒尺寸稍有增加。

根据 0.97KNNS–0.03BNKZ 陶瓷 SEM 照片,经过晶粒分布软件统计后,其粒径分布如图 2 所示。由图 2 可见,煅烧温度为 600 °C 和 950 °C 时,陶瓷内部存在大于 2 μ m 的晶粒;其余煅烧温度下制备的陶瓷,陶瓷晶粒尺寸都小于 2 μ m。随煅烧温度增加,陶瓷平均晶粒尺寸先减小后增加,从 0.40 μ m 降到 0.34 μ m,然后增加到 0.48 μ m。

图 3 为不同煅烧条件下 0.97KNNS–0.03BNKZ 陶瓷的 XRD 测试结果。由图 3 可见,所有陶瓷都

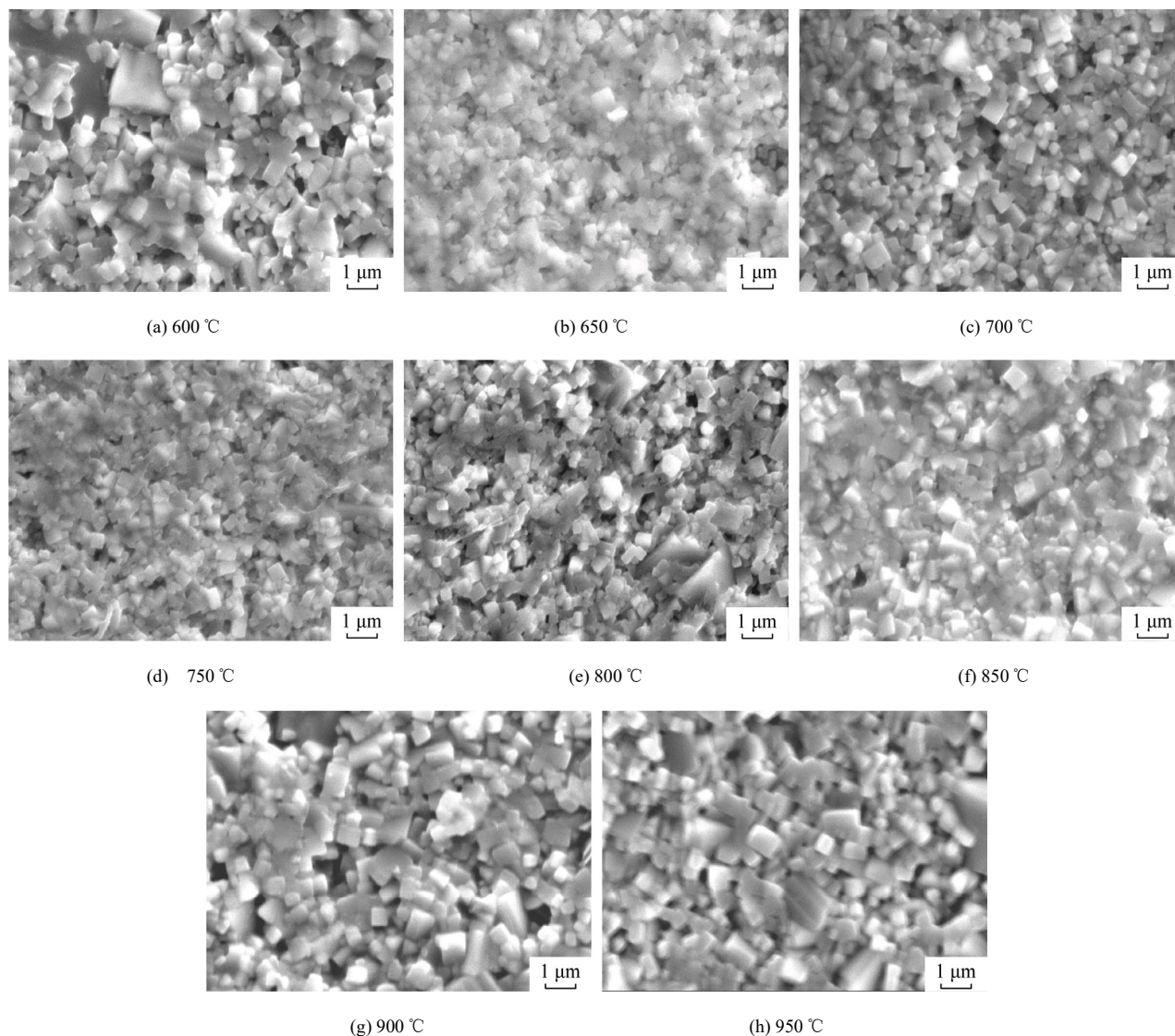


图 1 混合料在不同煅烧温度保温 3 h, 1180 °C 烧结温度保温 3 h 制备的 0.97KNNS-0.03BNKZ 陶瓷 SEM 照片
Fig. 1 SEM photographs of 0.97KNNS-0.03BNKZ ceramics 1180 °C for 3 h with different calcination temperatures

具有钙钛矿结构。根据衍射角 2θ 为 $44^\circ\sim 48^\circ$ 处的衍射峰来判断陶瓷的相结构(见图 3b), 随煅烧温度增加, (002)/(200)峰呈现单峰, 说明陶瓷具有伪立方相^[10-11], 峰的位置变化不大, 说明晶胞尺寸变化不大。与已研究 $(1-x)(K_{1-y}Na_y)(Nb_{1-z}Sb_z)O_3-xBi_{0.5}(Na_{1-w}K_w)_{0.5}ZrO_3$ 体系相比, (002)/(200)峰处的衍射角 2θ 偏大, 说明陶瓷晶胞尺寸偏小。为进一步证实陶瓷的晶体结构, 将在不同煅烧温度条件下制备的 0.97KNNS-0.03BNKZ 铁电陶瓷在 10 kHz 下进行介电常数随温度的变化测试, 如图 4 所示。由图 4 可见, 煅烧温度低于 950 °C 时, 陶瓷 Curie 温度(T_C)^[12]在 280 °C 左右; 当煅烧温度为 950 °C 时, 陶瓷的 T_C 为 320 °C。随煅烧温度增加, 陶瓷相应地介电常数 4 520 增加为 7 769。所有陶瓷的正交-四

方晶相的转变温度(T_{O-T})在 50~100 °C 之间, 比 KNN 的 T_{O-T} 降低了 100~150 °C^[9]。在室温下, 所有制备的陶瓷具有正交结构。结合 XRD 测试和介电常数-温度测试, 随煅烧温度的增加, 陶瓷室温下是具有畸变的正交结构, 但未能形成多相共存的结构, 其 Curie 温度有所增加。

图 5 为不同煅烧条件下 0.97KNNS-0.03BNKZ 陶瓷在频率为 10 Hz, 40 kV/cm 下的铁电性能测试结果。由图 5a 可见, 煅烧温度为 950 °C, $P-E$ 回线中最大极化强度(P_{max})最大。由图 5b 可见, 在矫顽场处陶瓷产生电流峰较大, 说明陶瓷中铁电畴易翻转增加极化强度。有 3 个原因使铁电畴易翻转: 1) 多相共存结构使铁电畴易转动; 2) 晶粒尺寸大, 铁电畴尺寸大降低畴钉扎的作用而利于铁电畴

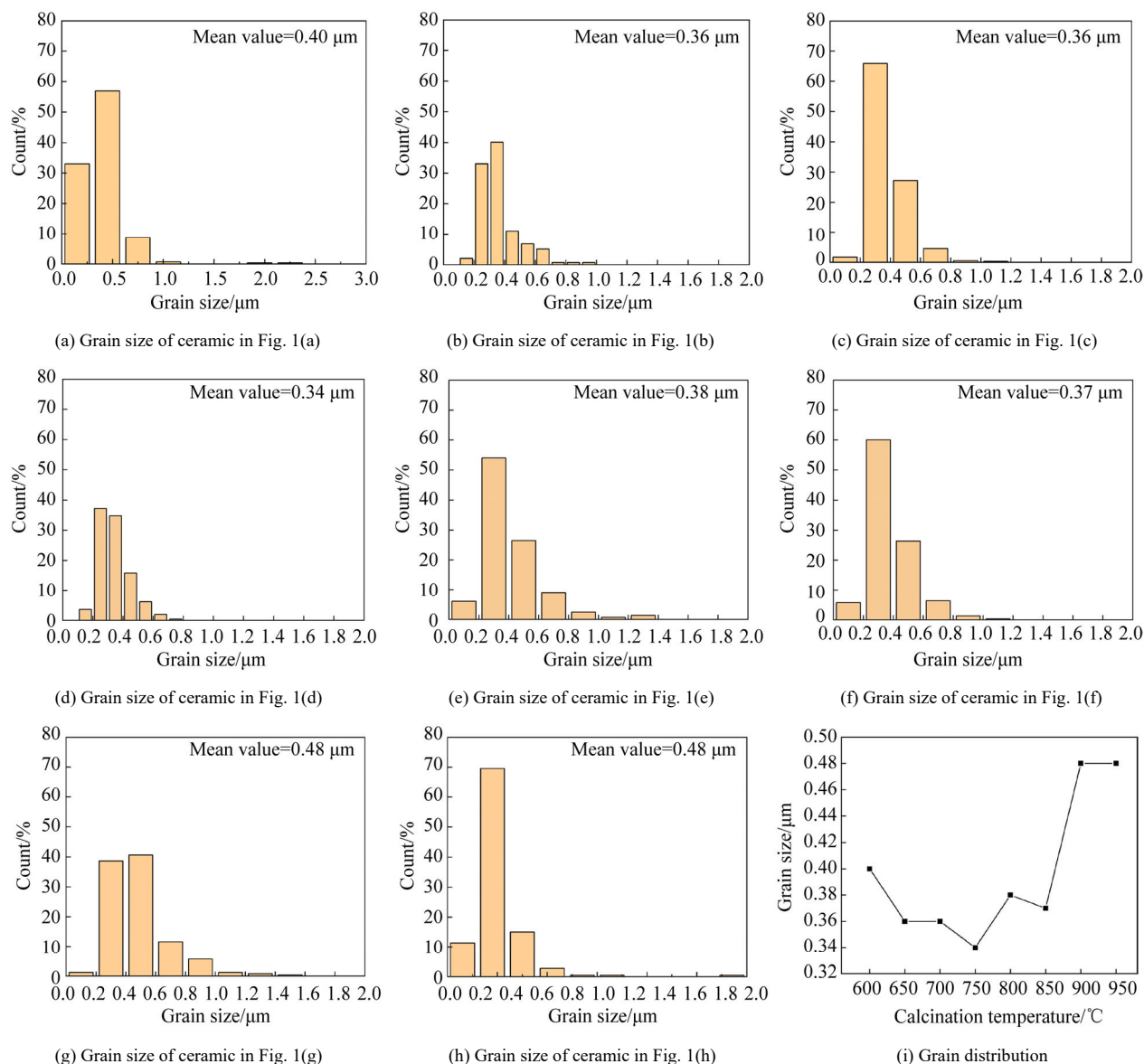


图2 不同煅烧温度下0.97KNNS-0.03BNKZ铁电陶瓷的晶粒尺寸统计和陶瓷平均晶粒与煅烧温度关系曲线

Fig. 2 Grain size distribution diagrams of 0.97KNNS-0.03BNKZ ceramics and grain distribution of ceramics at different calcination temperatures

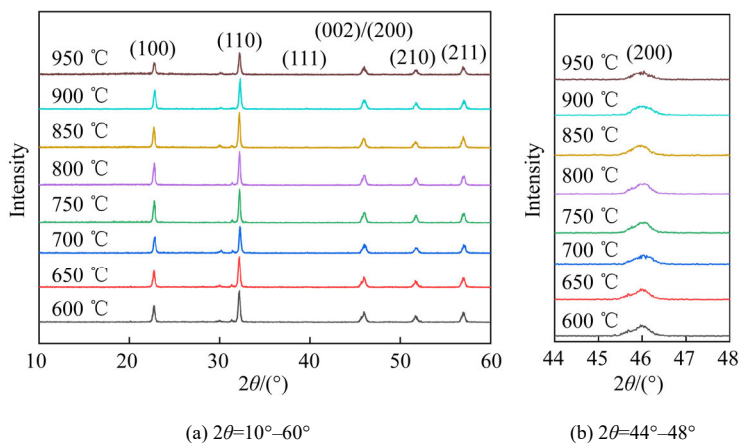


图3 不同煅烧条件下制备0.97KNNS-0.03BNKZ铁电陶瓷的XRD谱

Fig. 3 XRD patterns of 0.97KNNS-0.03BNKZ ferroelectric ceramics sintered at different calcination temperatures

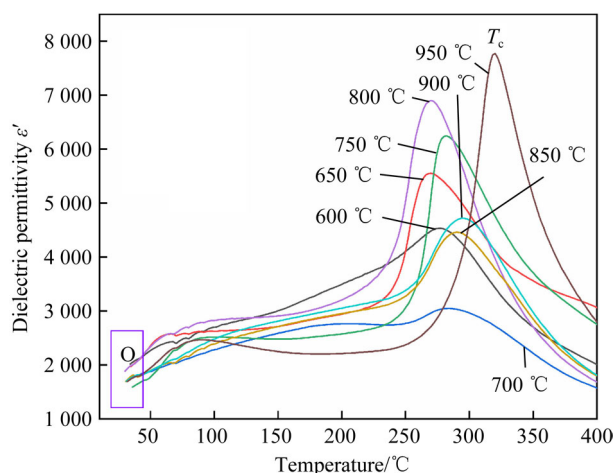


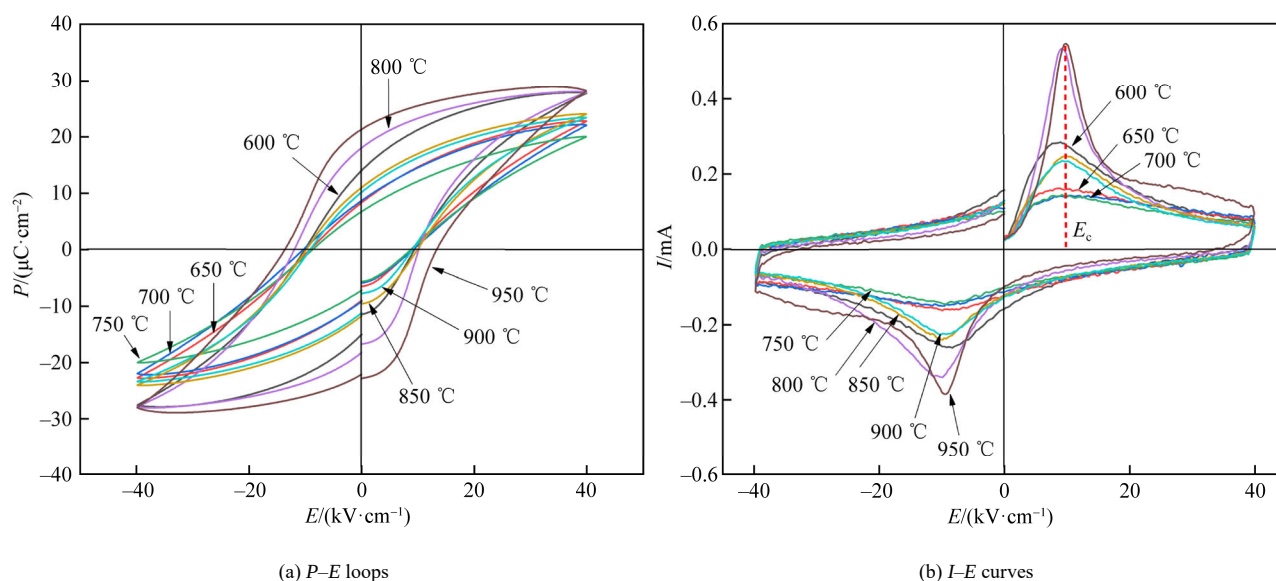
图 4 不同煅烧条件下制备的 0.97KNNs-0.03BNKZ 铁电陶瓷介电常数-温度关系曲线

Fig. 4 Temperature dependence of dielectric constant patterns of 0.97KNNs-0.03BNKZ ferroelectric ceramics sintered at different calcination temperatures

转动^[13-15]; 3) 过高的煅烧温度使陶瓷中 K、Na 离子挥发产生缺陷偶极子, 增强了铁电畴的翻转^[16]。与其它陶瓷相比, 煅烧温度为 950 °C 时, 陶瓷 P - E 回线中最大极化强度($P_{\max}$)剩余极化强度(P_r)明显变大, 由于晶粒尺寸大或者漏电流增加引起^[13]; 经过陶瓷粒径分布统计, 发现陶瓷平均晶粒尺寸为 0.48 μm , 与 900 °C 煅烧工艺制备的陶瓷平均晶粒尺寸一样, 如图 2 所示, 煅烧温度低 50 °C 制备的

陶瓷 P_r 很低; 考虑主要是漏电流增加引起 $P_{\max}$ 和 P_r 增加。陶瓷 P - E 回线中矫顽场(E_c)明显增大由于陶瓷中 K、Na 挥发产生缺陷偶极子使内电场增加, 陶瓷在较高的电场下电畴开始翻转。煅烧温度为 800 °C 时, $P_{\max}$ 和 P_r 较大, 陶瓷直径收缩率和密度高, 畸变的正交相利于铁电畴翻转进而增加极化强度; 煅烧温度为 600 °C, 陶瓷的 $P_{\max}$ 和 P_r 增大, 这是由于陶瓷密度低, 存在异常长大的晶粒利于铁电畴翻转, 进而增加极化强度。其它不同预烧温度下制备的陶瓷, $P_{\max}$ 和 P_r 区别不大, 其铁电性区别不大。总之, 煅烧温度为 800 °C 和 950 °C 时, 陶瓷的铁电畴易翻转导致极化强度较大约 $28 \mu\text{C}/\text{cm}^2$ 。

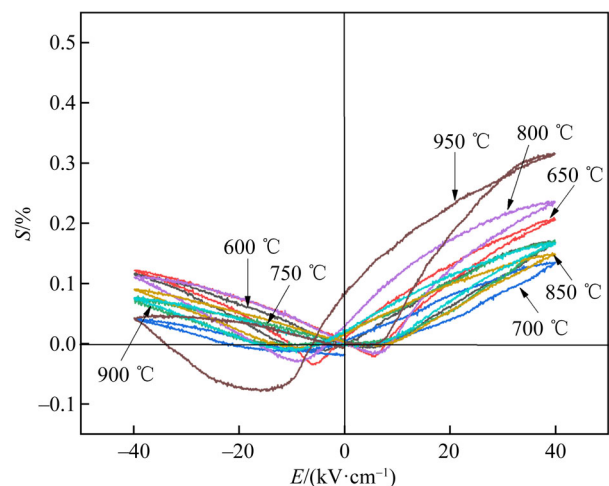
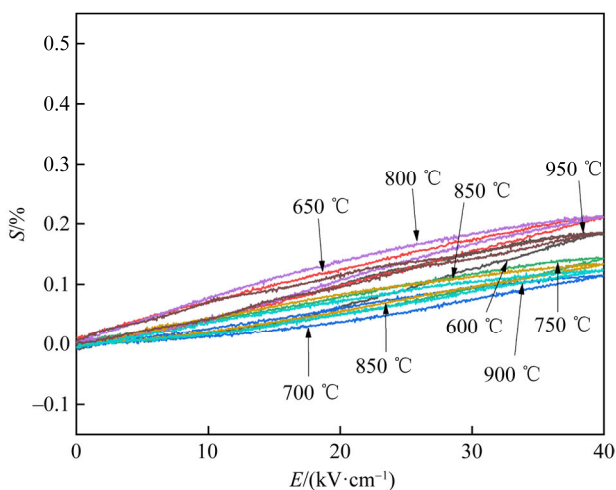
图 6 为不同煅烧温度条件下制备 0.97KNNs-0.03BNKZ 铁电陶瓷的应变性能。由图 6a 可见, 陶瓷具有不对称双极 S - E 曲线。煅烧温度为 950 °C 时, 陶瓷双极应变明显高于其它陶瓷, 达到 0.5% 左右且不对称, 应变曲线更加不对称是陶瓷内部产生 $V'_{\text{K/Na}} - V_{\text{O}}$ 缺陷偶极子产生内偏场导致^[17], 缺陷偶极子与铁电畴翻转之间作用增加陶瓷应变性能, 陶瓷单极应变最大达到 0.3%, 具有非常小的迟滞 11.9%。其余不同煅烧温度下制备的陶瓷, 双极应变性能在 0.2%~0.3% 之间, 区别不大。图 6b 是陶瓷单极应变, 煅烧温度为 950 °C 时陶瓷单极应变与其它煅烧条件下制备的陶瓷, 其应变性能区别不大在 0.2%~0.3% 之间。



P is polarization; E is electric field intensity; I is electric current.

图 5 在不同煅烧温度条件下制备的 0.97KNNs-0.03BNKZ 铁电陶瓷的铁电性能

Fig. 5 Ferroelectric properties of 0.97KNNs-0.03BNKZ ceramics sintered at different calcination temperatures

(a) Bipolar S - E curves(b) Unipolar S - E curves

S is strain.

图 6 在不同煅烧温度条件下制备的 0.97KNNS-0.03BNKZ 铁电陶瓷的应变性能

Fig. 6 Strain properties of 0.97KNNS-0.03BNKZ ferroelectric ceramics, at different calcination temperatures

3 结论

随煅烧温度从 600 °C 增加到 950 °C, 0.97KNNS-0.03BNKZ 陶瓷具有相同的畸变的正交结构, 但其直径收缩率, 相对密度先增加后减小。煅烧温度为 800 °C 时, 陶瓷致密性最高; 煅烧温度为 600 °C 和 950 °C 时, 陶瓷致密性最低。

致密性高和低的陶瓷铁电畴易翻转具有较大的极化强度。煅烧温度为 950 °C 时, 由于铁电畴易翻转以及与缺陷偶极子相互作用是使其在 60 kV/cm 电场下其双极应变达到 0.5%。而其余陶瓷在 60 kV/cm 电场下其双极应变在 0.2%~0.3% 之间。总之, 煅烧

温度对 0.97KNNS-0.03BNKZ 陶瓷晶体结构影响不大, 但对陶瓷致密性影响很大进而影响其应变性能。

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Effect of Calcination Temperature on Strain Properties of Potassium Sodium Niobate Based Ferroelectric Ceramics

WANG Mengli¹, SANG Xiuji¹, ZHOU Jing¹, LI Fang¹, LI Min²

(1. Weifang Vocational College, Weifang 262737, Shandong, China; 2. Chizhou University, Chizhou 247000, Anhui, China)

Extended Abstract

Introduction Ferroelectric ceramics generate a strain property in electric field due to the inverse piezoelectric effect and ferroelectric domain switching, and these ceramics can be made as key components of actuators. Lead-based ferroelectric ceramics are widely used in actuators, but their high lead level is harmful to human-being health and environment. $(K_{1-x}Na_x)NbO_3$ -based ceramics replace lead-based ceramics for actuators applications. $(K_{1-x}Na_x)NbO_3$ -based ceramics with a multi-phase coexistence structure at room temperature have a high strain due to the possible increasing polarization direction. The classical $(1-x)(K_{1-y}Na_y)(Nb_{1-z}Sb_z)O_3-xBi_{0.5}(Na_{1-w}K_w)_{0.5}ZrO_3$ ($0 \leq x \leq 0.05$, $0.40 \leq y \leq 0.68$, $0 \leq z \leq 0.08$, $0 \leq w \leq 1$) (KNNS-BNKZ) system can be adjusted to have rhombohedral-tetragonal (R-T), rhombohedral-orthogonal-tetragonal (R-O-T), orthogonal-tetragonal (O-T) phases coexisted structures to increase the strain property. When the system is used to construct the coexistence structure, the composition and process need to be finely regulated, especially the raw material calcination or pre-firing process. Pre-firing is a solid-phase reaction of various raw materials at a certain temperature, and the purpose is to synthesize the crystal structure of the target component without raw material components. The activity, particle size and uniformity of the pre-fired powder have a great influence on the difficulty of green sintering and the electrical properties of ceramics. The pre-firing temperature affects the phase coexist structures of $0.96(K_{0.5}Na_{0.5})(Nb_{0.96}Sb_{0.04})O_3-0.04Bi_{0.5}(Na_{0.5}K_{0.5})_{0.5}ZrO_3$ ceramic coming from KNNS-BNKZ system, but the effect of the strain properties of ceramics is not reported yet. In this paper, $0.97(K_{0.48}Na_{0.52})(Nb_{0.97}Sb_{0.03})O_3-0.03Bi_{0.5}(K_{0.48}Na_{0.52})_{0.5}ZrO_3$ (0.97KNNS-0.03BNKZ) with R-T was designed according to KNNS-BNKZ system. KNN-based ceramics with multi-phase coexistence for improving their strain properties were constructed via adjusting the pre-firing temperature. In addition, the effect of pre-firing temperature on the phase structure, dielectric properties, ferroelectric properties and strain properties of 0.97KNNS-0.03BNKZ ferroelectric ceramics was investigated.

Methods For the preparation of 0.97KNNS-0.03BNKZ ferroelectric ceramics by a solid-phase sintering method, the ingredients were made according to the chemical formula, and various raw materials were mixed and ground with absolute ethanol in a ball mill with zirconia balls. After 12 h milling, the slurry was dried. The mixture of 0.97KNNS-0.03BNKZ components of 20.0 g in a crucible was calcined at 600–950 °C for 3 h. After milling and drying, the powder was pressed into green discs with the diameter of 13 mm. The upper and lower surfaces of the green discs were buried with the same calcination powder, covered with alumina crucible then sealed with alumina powder. Finally, the green discs were sintered in a high-temperature furnace at 1 180 °C for 3 h. The ceramic samples were obtained after cooling in the furnace.

The samples were not polished and thermally corroded. The surface morphology of the ceramics was determined by a model Smartlab 3 kW scanning electron microscope after direct cleaning and drying. The density of the samples was analyzed by the Archimedes drainage method. After grinding the surface of samples, the phase structure of the ceramics was characterized by X-ray diffractometer (XRD). Their ferroelectric and strain properties were determined at 10 Hz by a model Precision Premier II ferroelectric system. Their permittivity was measured at 10 kHz by a model TZDM permittivity instrument.

Results and discussion The effect of calcination temperature (*i.e.*, 600–950 °C) on the diameter shrinkage, density, relative density, microstructure, crystal structure, dielectric properties, ferroelectric properties and strain properties of 0.97KNNS-0.03BNKZ ceramics was analyzed. The results show that the diameter shrinkage density and relative density of these ceramics firstly increase and then decrease with the increase of the calcination temperature. The ceramics calcinated at 800 °C have the maximum relative density (*i.e.*, 94.9%), while the ceramics calcinated at 600 °C and 950 °C have the minimum relative density (*i.e.*, 80.3% and 80.4%). All of the ceramics have the same distorted orthogonal crystal structure based on the XRD patterns and temperature-dependence of dielectric constant. Their Curie temperature increases from 280 °C to 320 °C, while their dielectric constant increases from 4 520 to 7 769. The maximum polarization strength (P_{max}) of the ceramics at 600, 800 °C and 950 °C is obtained due to the easy domain switching for the high or small relative density of ceramics. At 950 °C, the bipolar strain of the ceramics reaches 0.5% at 60 kV/cm because the ferroelectric domain is easy to switching, and the interacts between $V'_{K/Na} - V'_O$ defect dipoles and domain switching. At 600–900 °C, the strain properties of the ceramics change slightly (*i.e.*, 0.2%–0.3% strain). The unipolar strain properties of ceramics calcinated at different temperatures are similar.

Conclusions The pre-firing had little effect on the crystal structure of 0.97KNNS-0.03BNKZ ceramics, but had a great effect on the density and strain performance of the ceramics. When the calcination temperature was 950 °C, the bipolar strain of the ceramics reached 0.5% at 60 kV/cm, because the ferroelectric domain was easy to switching and the interacts between $V'_{K/Na} - V'_O$ defect dipoles and domain switching.

Keywords calcination; potassium sodium niobate ceramics; Piezoelectric property