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Synthesis of Microcomponent Doped Strontium Titanate Single Crystal Special Raw Material Powder by Solid Phase Method

Yuting Tang[1,a], Jian Tang[1,b,*], Hao Wu[2,c], Jixuan Dong[1,d,] Meiqi Li[1,e], Erque Zhao[1,f] and Shidan Wang[1,g]

[1]*College of New Energy, Shenyang Institute of Engineering, Shenyang 110136, Liaoning, China*
[2]*HuaNeng YingKou Co-generatian Co.Ltd, Yingkou 115003, China*
[a]*2660872386@qq.com,* [b]*ican299@126.com,* [c]*86518948@qq.com,* [d]*1507506800@qq.com,*
[e]*2662818759@qq.com,* [f]*2224883156@qq.com,* [g]*1153573546@qq.com*
[*]*corresponding author*

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Abstract: This article elaborated on the preparation process and performance characteristics of a novel solid-phase method for synthesizing microcomponent doped strontium titanate single crystal specialized raw material powder. A series of characterization methods, including X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier transform infrared (FT-IR) spectra, were used to characterize the structures of $SrTiO_3$ particles. The main results showed that, the prepared micro component doped strontium titanate single crystal specialized raw material powder has a complete structure, excellent morphology, and uniform chemical composition.

With the continuous development of science and technology, the demand for high-performance and high-quality raw materials is becoming increasingly strong. In the field of materials science, strontium titanate single crystal has attracted great attention from researchers as an important material widely used in optical, electronic and other fields.However, there are various preparation methods for this material, each with its own advantages and disadvantages. Among them, solid-state synthesis technology has been proven to be an effective way to prepare strontium titanate single crystals[1]. However, there are often issues with purity and uniformity during solid-state synthesis, which affect the performance and reliability of the material. To address this issue, the micro component doping technology has become a new improvement in solid-state synthesis technology. This article will elaborate on the preparation process and performance characteristics of a novel solid-phase method for synthesizing microcomponent doped strontium titanate single crystal specialized raw material powder. Firstly, introduce the principles and significance of solid-state synthesis and microcomponent doping. Then, the preparation process and various analysis methods of the new raw material powder are elaborated in detail, including X-ray diffraction (XRD), scanning electron microscopy (SEM), Fourier transform infrared (FT-IR) spectra, etc. Finally, discuss the performance, application prospects, and future prospects of the raw material powder.

1. Solid-phase Chemistry

Solid phase chemical reaction refers to the reaction between solid reactants, in which the solid reactants undergo heat treatment to obtain solid products with new structures, compositions, or properties[2]. Compared to solution or gas phase methods, solid-state chemical reactions have higher reactivity and lower side reactivity, and can prepare high-quality and high-purity products that are suitable for mass production. Therefore, solid-state synthesis technology has been widely applied in the field of materials science[3].

As an important functional material, the preparation methods of strontium titanate single crystals are also very rich[4]. In the past, the preparation of strontium titanate single crystals was mainly through solution or hydrothermal synthesis methods. The solution method is suitable for producing large quantities of low-quality products, but the preparation process often requires long-term precipitation and separation treatment, and the purity and uniformity of the products are difficult to guarantee[5]. The hydrothermal synthesis method generally requires high reaction conditions, such as high pressure, high temperature, and long-term reactions, while it is difficult to control the microstructure and composition uniformity[6].

The solid-state synthesis technology not only solves the problems of solution and hydrothermal methods, but also has the advantages of producing high-quality and high-purity products. In the solid-state synthesis process, by controlling parameters such as reaction temperature and reaction time, solid-state ion exchange and phase conversion reactions can be achieved, thereby obtaining crystals with excellent physical and chemical properties[7].

2. Micro-component Doping

Strontium titanate single crystal is a composite material with various functions such as optical, electrical, acoustic, magnetic and crystallographic. Among them, trace impurities can introduce new components in the crystal, and these components play an important role in the performance and properties of the material. In recent years, its micro-component doping technology has become an important improvement option for solid-phase synthesis techniques[8].

Micro-component doping technology refers to the introduction of small amounts of impurities into strontium titanate single crystals to adjust the ionic components and content within the crystal, thus improving the optical, electrical, magnetic and thermal properties of the material, and thus its practical value. Through micro-component doping, the characteristics of the material in terms of crystal structure, internal arrangement and surface morphology can be changed, thus altering the physical and chemical properties of the material. For example, strontium titanate single crystals can be made to exhibit different color and luminescence properties by introducing Cr, Mn, Ni, Co, and Cu plasma doping[9].

In the preparation process, the micro-component content is usually required to be as low as 10^{-2} to 10^{-4}, or even lower. Due to the presence of small amounts of impurities, microcomponent doping can have an impact on the structural, physical, and chemical properties of the crystalline material. Therefore, the principles, mechanisms, processes and properties of micro-component doping need to be thoroughly investigated in order to achieve optimal results in material preparation and applications.

3. Preparation Process

In order to prepare high-quality micro component doped strontium titanate single crystal specialized raw material powder, we adopt the following preparation process.

3.1. Preparation of Raw Materials

The main raw materials used in this experiment :$Ti(OCH(CH_3)_2)_4$ $SrCO_3$ $Y(NO_3)_3\,6H_2O$ $Er(NO_3)_3\,5H_2O$ $Cr(NO_3)_3\,9H_2O$ $Mn(NO_3)_2\,4H_2O$ $Ni(NO_3)_2\,6H_2O$ $Co(NO_3)_2\,6H_2O$ $Cu(NO_3)_2\,3H_2O$ $KClO_4$和 $NaNO_3$ Among them, both :$Ti(OCH(CH_3)_2)_4$ $SrCO_3$ and $NaNO_3$ are all laboratory prepared reagents, and other reagents need to be pre-treated first.

3.2. Preprocessing

In this experiment, all ionic dopants need to be pre-treated. First, the required strontium titanate ratio was mixed, followed by the addition of appropriate solvents and surfactants, and stirred at 80℃ for 12 h. Then the temperature is raised to 150℃, fully dried and washed, and finally the pure microcomponent doping raw material is obtained.

3.3. Solid Phase Reaction Process

Strontium titanate was mixed with pre-treated microcomponent dopant in a certain proportion, taking Ti/Sr=1/1 as an example. The mixture is then placed in a high temperature furnace for high temperature solid reaction. The reaction temperature ranges from 800 ℃ to 1100℃, and the reaction time ranges from 6 to 24 h. In the process, proper heating and stirring should be done to ensure even reaction. After solid phase reaction is completed, the product powder is separated, washed and dried. Finally, pure microcomponent doped strontium titanate single crystal raw material powder is obtained.

3.4. Analysis and Characterization

The prepared microcomponent doped strontium titanate single crystal powder was analyzed and characterized by three types: structure characterization (XRD), morphology characterization (SEM) and chemical composition characterization (FTIR).

XRD analysis was carried out by RIGAKU D/MAX-RA X-ray diffractometer, the voltage was 40 kV, the current was 40 mA, and the scanning range was between 5~80 °. The SEMs experiment was analyzed with Eside S-4800 scanning electron microscope, and the acceleration voltage was 10 kV. Metal injection and conductive treatment of the samples were required to obtain high-quality SEM images. The FTIR experiment was analyzed by Fourier transform infrared spectroscopy with Thermo Nicolet Nexus 470 Fourier transform infrared spectrometer.

4. Performance Analysis

4.1. Structural Characterization

The XRD patterns show the structural characteristics of the prepared microcomponent doped strontium titanate single crystal powder. As shown in Figure 1, the material exhibits a single tetragonal structure without significant impurities and defects. All the diffraction peaks can be mapped to the JCPDS meter card (No. 65-1497), indicating that the prepared material is highly crystalline and of good purity. It can also be seen from the figure that the basic crystal structure of strontium titanate single crystal will not be changed by adding a small amount of dopant.

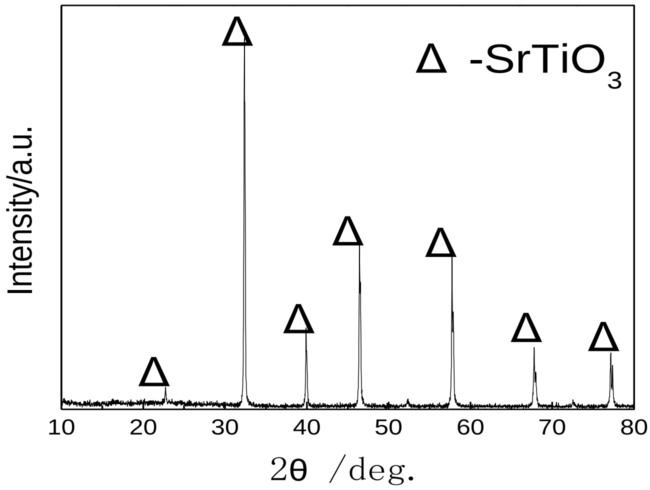

Fig. 1. XRD patterns of $SrTiO_3$ powders

4.2. Morphology Characterization

SEM micrograph show the surface morphology and internal structure of the prepared raw material powder doped strontium titanate single crystal. As shown in Figure 2, the sample has a uniform crystal structure and a relatively clear surface. The microcomponent dopants can be evenly distributed and occupy the lattice position on the crystal, which is consistent with the results in the XRD pattern. The SEM micrograph also showed that the powder had excellent performance in the aspects of flatness, smoothness and evenness.

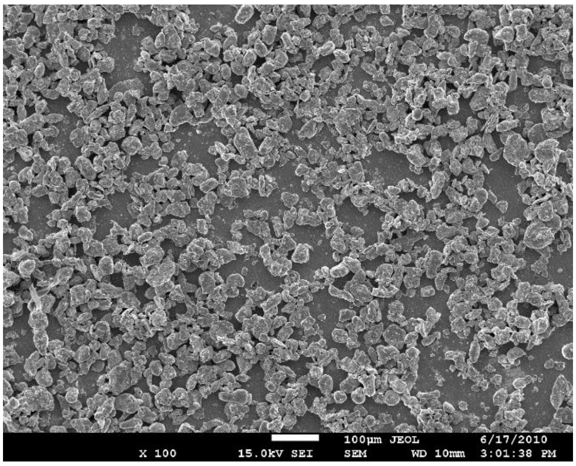

Fig. 2. SEM micrographs of $SrTiO_3$ powders

4.3. Chemical Composition Characterization

The chemical composition and structural characteristics of the prepared microcomponent doped strontium titanate single crystal powder were demonstrated by FTIR spectra. As shown in Figure 3, the spectral peak of the material is between 4000~400 cm^{-1}, and the main distribution is between

500~800 cm^{-1} and 1400~1600 cm^{-1}. These peaks can be attributed to ionic bond vibrations or molecular recognition of the $SrTiO^3$ crystal.

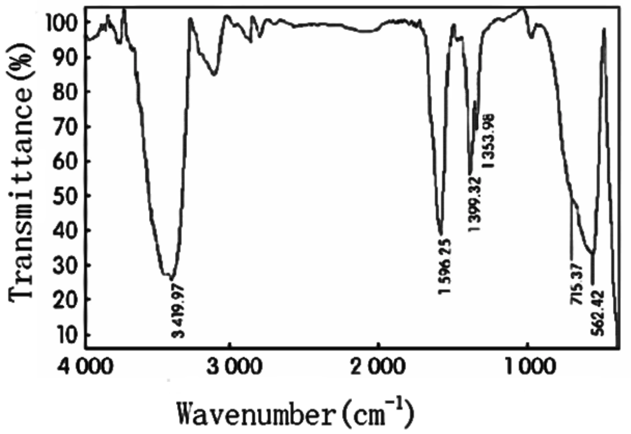

Fig. 3. FTIR spectra of $SrTiO_3$ powders

5. Application and Prospects

From the above analysis results, it can be seen that the prepared micro component doped strontium titanate single crystal specialized raw material powder has a complete structure, excellent morphology, and uniform chemical composition. At the same time, this material also exhibits excellent optical, electrical, and thermal properties, and has broad application prospects.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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