Fabrication and Characterization of Hexagonal SrMnO₃ Nanofibers by Electrospinning

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Abstract. SrMnO₃/Polyvinylpyrrolidone (PVP) composite nanofibers have been prepared successfully by electrospinning from Cerous(II) nitrate and Manganese(II) acetate tetrahydrate, after the heat treatment at 800 °C for 3 h, the hexagonal SrMnO₃ nanofibers was obtained. The effect of PVP concentration was investigated. The size and morphology, phase information, thermal properties of nanofibers were characterized by SEM, EDX, XRD, TGA, FT-IR, respectively.

1 Introduction

Electrospinning technique is extensively employed to synthesize some ultrafine, continuous and uniform diameter nanofibers of polymers, composites and ceramics for its advantages such as briefness, versatility, time saving and low cost [1, 2]. The method of electrospinning has some advantage such as high porous structure, low density and high specific surface area in synthesis of nanofibers. [3, 4]. The formation of ceramic nanofibers by electrospinning was firstly reported by Shao et al. [5] in 2002. As far, many one-dimensional ceramic materials have been synthesized by electrospinning such as BaTiO₃, YMnO₄, CaSnO₃, MgWO₄, etc., [2-12].

The SrMnO₃ is extensively used as antiferromagnetic insulator with a crystal structure of G-type[13,14]. Due to the special skeletal structure which was consisted of a three dimensional network of MnO₆ octahedra, the SrMnO₃ sample has some properties such as oxygen nonstoichiometry, electronic properties, thermochromism, etc [15].

SrMnO₃ powders have been synthesized with many methods such as high temperature solid-state reaction, coprecipitation [16], sol-gel, etc [17-20]. High temperature solid-state reactions need a very high temperature. Furthermore, obtained products with this technique are agglomerated in a big grain size. Coprecipitation and sol-gel processes can prepare nanopowders in a lower temperature. Nanofibers can be prepared via electrospinning combined with sol-gel process. As far as I know, the synthesis of SrMnO₃ nanofibers has never been reported. Recently, the mixture of inorganic and organic salts dissolving in Polyvinylpyrrolidone (PVP) as starting materials, inorganic-polymeric fibers was...
synthesized by electrospinning, the inorganic-polymeric fibers would transform into nanofibers by subsequent calcinations at high temperature. Here we report the synthesis and characterization of SrMnO$_3$ nanofibers for its future applications.

2 Experimental

Cerous(II) nitrate and Manganese(II) acetate tetrahydrate were used as the raw materials for the synthesis of SrMnO$_3$ nanofibers. PVP (MW = 1,300,000) was used as viscosity-controlling agent. 4 mmol Cerous(II) nitrate and 4 mmol Manganese(II) acetate tetrahydrate were dissolved in 3 mL demonized water, 11 mL ethanol aqueous and a certain amount of PVP was added and the solution was stirred for 12 h at room temperature, then homogeneous hybrid sol was obtained. The above precursor sol was loaded in 20 ml plastic syringe of 25 gauges with stainless steel needle. The distance between the spinneret and collector was fixed at 10 cm and the high-voltage supply was maintained at 15 kV. The spinning rate was controlled at 1.5 mL/h. inorganic-polymeric fibers was collected on the collector. These fibers were calcinated at a rate of 2 °C/min and remained 3 h at 800 °C in air atmosphere. Thus, hexagonal SrMnO$_3$ nanofibers was obtained.

X-ray diffraction (XRD) analysis were performed on Rigaku Geiger flux instrument equipped with Cu-Kα(λ= 0.1506 nm) radiation, Scans were made from 10 ° to 70 °at the speed of 3 °/min, and the step was 0.05°. The size and morphology of SrMnO$_3$ fibers were observed with JEOL JSM-6390 scanning electron microscope (SEM). Energy dispersive X-ray (EDX) spectrograph was recorded for the elemental analysis to investigate the phase purity of SrMnO$_3$ nanofibers using INCA 200 EDS, attached with SEM. Thermogravimetric analysis was carried out on TA Q50 in nitrogen atmosphere, and the temperature-rising rate was 10 °C/min. Fourier transformation infrared (FT-IR) spectroscopy was record on Perkin Elmer spectrum 100.

3 Results and Discussion

**SEM and EDX Analysis.** The results of SEM images (Fig. 1) show that the concentration of PVP had a significant effect on the formation, uniformity and homogeneity of nanofibers. The size and morphology has marked difference under the four conditions. Under 6%, non-uniform fibers with beaded structure are formed, reached 8%, the beaded structure disappears and the fibers become uniform. This is because that surface tension and viscosity are correspondingly increased, with increasing of PVP concentration. Resistance airflow tensile force and static electricity needing to overcome is becoming higher in the electrospinning process. For PVP concentration of 10%, the fibers are more uniform than that of low PVP concentration. These results are consistent well with the published literature [10, 11].

Fig. 2 (a-b) shows the SEM images of the sample before and after calcinations. In Fig. 2(a), the randomly oriented hybrid fibers with smooth surface and average diameter of 300–400 nm can be observed. After annealed at 800 °C (Fig. 2(b)), the fibrous structure is retained on the whole except that a small amount of fibers are broken during the calcinations process. And the average diameter is reduced to 150–200 nm due to the evaporation and decomposition of PVP and volatile components. The fibers surface becomes rough because of the decomposition of PVP and the formation of crystallites. SrMnO$_3$ nuclei also grow to form larger nanoparticles. Fig. 2(c) shows the EDX of SrMnO$_3$ nanofibers annealed at 800 °C. In the EDX pattern, all peaks are corresponding to Sr, Mn and O, except Au peak, indicate formation of strontium manganate. Au peak appears because Au is sprayed onto the nanofibers before scanning in order to get high quality
morphology images. The result shows that the SrMnO$_3$ nanofibers hold good purity after removal of PVP.

Fig. 1 SEM images of PVP/SrMnO$_4$ with different PVP concentration of (a) 4%, (b) 6%, (c) 8% and (d) 10%

Fig. 2 SEM images of samples (a) before annealed, (b) annealed at 800 °C and (c) EDX of SrMnO$_3$ nanofibers annealed at 800 °C.

**XRD Analysis.** Fig. 3 shows the XRD pattern of SrMnO$_3$ nanofibers annealed at 800 °C. As indicated in Fig. 3, strong peaks are observed at 2θ = 32.84° associated with (110) planes. Other main diffraction peaks at 2θ = 27.22, 35.19, 43.19, 48.90, 58.62, 60.17 and 68.87° are assigned to the diffraction of (102), (103), (202), (203), (300), (213) and (220) crystal facets, respectively. All diffraction peaks show good consistency with JCPDS, Card No. 24-1213 of perovskite phase of SrMnO$_3$ [19]. A single hexagonal perovskite system was determined. No typical peak of polymer was observed in Fig. 3, indicated that PVP was decomposed and removed after the heat treatment at 800 °C.

**Thermal Properties.** The TGA curve of SrMnO$_3$/PVP composite nanofibers was shown in Fig. 4. The weight loss has 3 stages, The first weight loss is 11.4 % below 120 °C, which was caused by the loss of surface adsorbed and residual moisture [21-23]. The weight loss (~35.5 weight. %) between 250 and 400 °C is due to the evaporation of organic contents (PVP)[8, 11]. Similarly, the weight loss (~33.7 weight. %) during 400-700 °C is considered due to the decomposition of the organometallic precursor (manganese acetate) and strontium nitrate. The weight loss is completed below 700 °C and total weight loss is about 80.4%. Above 700 °C, no weight loss has been observed and the TGA curve becomes horizontal. The TGA curve result indicates that SrMnO$_3$ fibers sample can be fabricated at a temperature of 700 °C and above.

**FT-IR Spectrum.** Fig. 5(a)–(c) shows the FT-IR spectra of PVP, SrMnO$_3$/PVP
composite fibers and SrMnO$_3$ nanofibers, respectively. For PVP sample, the broad band around 3600–3200 cm$^{-1}$ corresponds to hydrogen bonded O-H stretching vibration. The triplet peaks present at 2954 cm$^{-1}$ corresponds to the asymmetric and symmetric C-H stretching vibrations of methyl groups (from acetate) [24]. While the other three dominant peaks at about 1654, 1442 and 1292 cm$^{-1}$ are due to the stretching vibration of C=O, C-H and C-N bond, respectively [25]. As shown in Fig. 5(b), the C=O stretching vibration characteristic peak red-shifts to 1652 cm$^{-1}$ in the composite fibers. The C-H stretching vibration peaks blue-shift to 2956 and 1444 cm$^{-1}$ respectively. The bands at 1425 cm$^{-1}$ in the PVP fibers disappears in the composite fibers and the stretching of C-N at 1292 cm$^{-1}$ is weakened. In Fig. 5(c), all the PVP peaks vanish, indicating that the PVP was full decomposed. Three new peaks appear at 765, 663, and 542 cm$^{-1}$. These new peaks are ascribed to the stretching vibration of metal-oxide (M-O) bonds in SrMnO$_3$, which matches well with the published literature [19]. FT-IR results are in good agreement with the SEM, XRD and TGA results.

![Fig.3 XRD patterns of samples annealed at 800 °C and (d) JCPDS card no 24-1213, standard phase of SrMnO$_3$.](image1)

![Fig. 4 TGA curve of SrMnO$_3$/PVP nanofibers.](image2)

![Fig.5 FT-IR spectrum of samples (a) PVP fibers, (b) SrMnO$_3$/PVP nanofibers, and (c) SrMnO$_3$ nanofibers.](image3)
4 Conclusions

SrMnO$_3$/PVP composite nanofibers with a diameter of 300–400 nm was successfully fabricated by electrospinning technique and pure hexagonal SrMnO$_3$ fibers of diameter of 150–200 nm was synthesized by the heat treatment of SrMnO$_3$/PVP composite nanofibers at 800 °C. PVP concentration plays an important role in the formation, uniformity and homogeneity of nanofibers, when the concentration reached 8%, the fiber became uniform. The SrMnO$_3$ fibers have hexagonal perovskite system structure which was determined by XRD. The EDX, XRD, TGA and FT-IR results indicated that PVP was decomposed and removed after the heat treatment at 800 °C.

References