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Facile synthesis of porous forsterite nanofibres by direct electrospinning method based on the Kirkendall effect

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ABSTRACT

Porous forsterite nanofibres were prepared by direct electrospinning method. The phase composition, morphology and pore structure of nanofibres were characterized. The porous nanofibres had high-purity for forsterite phase, mesoporous structure and a high specific surface area of 31.1 $m^2 g^{-1}$. The porous formation in forsterite nanofibres was driven by the Kirkendall diffusion effect. As the Mg ions diffused into SiO_2 component faster, the forsterite phase formed on the silica side, and the previous voids occupied by Mg ions left behind and evolved into the Kirkendall pore structure. The porous forsterite nanofibres had a low thermal conductivity of 0.0463 W/m·K, indicating a potential application for thermal insulation.

1. Introduction

Forsterite nanofibres have the favorable properties of forsterite materials, such as low thermal conductivity, good chemical stability and excellent biocompatibility [1–3]. The forsterite nanofibres were used in many applications, such as thermal insulation, adsorption and tissue engineering [4–6]. The porous nanofibres with high specific surface area could improve the performance of materials. For example, the porous fibres with less solid content have lower thermal conductivity [7]. However, forsterite fibres were usually synthesized by the traditional methods, such as sol-gel method [3,8–10], and their thermal conductivity is relatively high because of their solid structure. It is still challengeable for developing a facile route to the preparation of the porous forsterite nanofibres.

The electrospinning technique was an easy and cost-effective preparation method for ceramic nanofibres [11]. The advantages of the method, such as fine diameter and large specific surface area, could improve the performance of nanofibres used in absorption, thermal insulation and bone tissue engineering [12–14]. But the porous ceramic nanofibres prepared by traditional electrospinning are usually generated by adding phase-separation component, which required more complex procedures and designated devices.

Recently, it was found that the porous ceramic nanofibres can be synthesized by the direct electrospinning technique without phase-separation component, which is based on the Kirkendall diffusion effect [15]. In SiO_2-MgO system, the Kirkendall diffusion effect was also found [16]. Thus, the porous forsterite nanofibres were fabricated by direct electrospinning method based on the Kirkendall diffusion effect here.

2. Experimental

The precursor solution was obtained after dissolving 0.15 g $MgCl_2$ powders with 0.24 ml TEOS and 15 ml CH_2Cl_2 by magnetic stirring. The dried gel was prepared by heating the solution in an oven from room temperature to 110 °C for 24 h. 0.5 g PVP (Mw = 1,300,000) and 8 ml anhydrous ethanol was added into the dried gel with stirring for 2 h in order to obtain the electrospinning solution. Then the solution was loaded into a glass syringe with a stainless steel needle (nozzle size of 0.8 mm). The fixed ejection rate and electro-static voltage was 1.0 ml/h and 15.0 kV, respectively. The distance was kept at 13 cm between the aluminum collector and the needle. The precursor fibres were collected and then calcined at 550 °C, 850 °C and 1000 °C for 1 h with heating rate of 3 °C/min.

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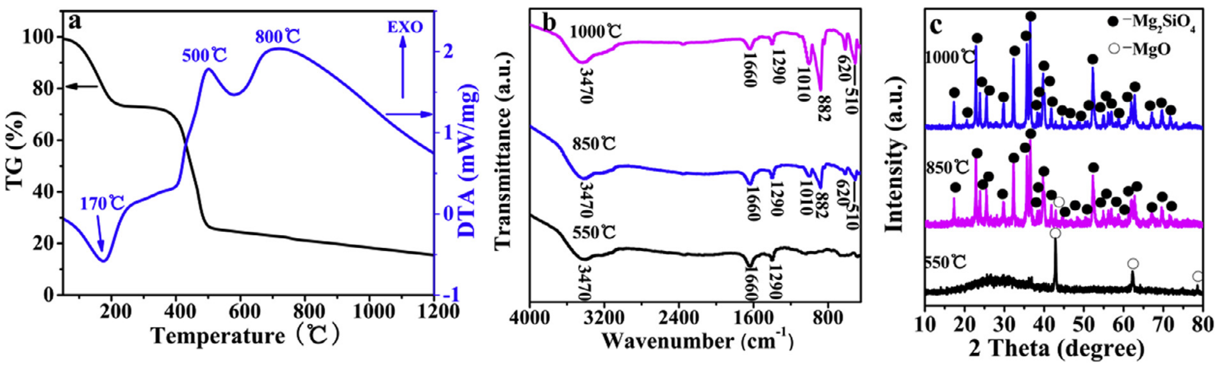

Fig. 1. DTA-TG curve (a) of forsterite gels, FTIR spectrums (b) and XRD patterns (c) of fibres calcined at different temperatures.

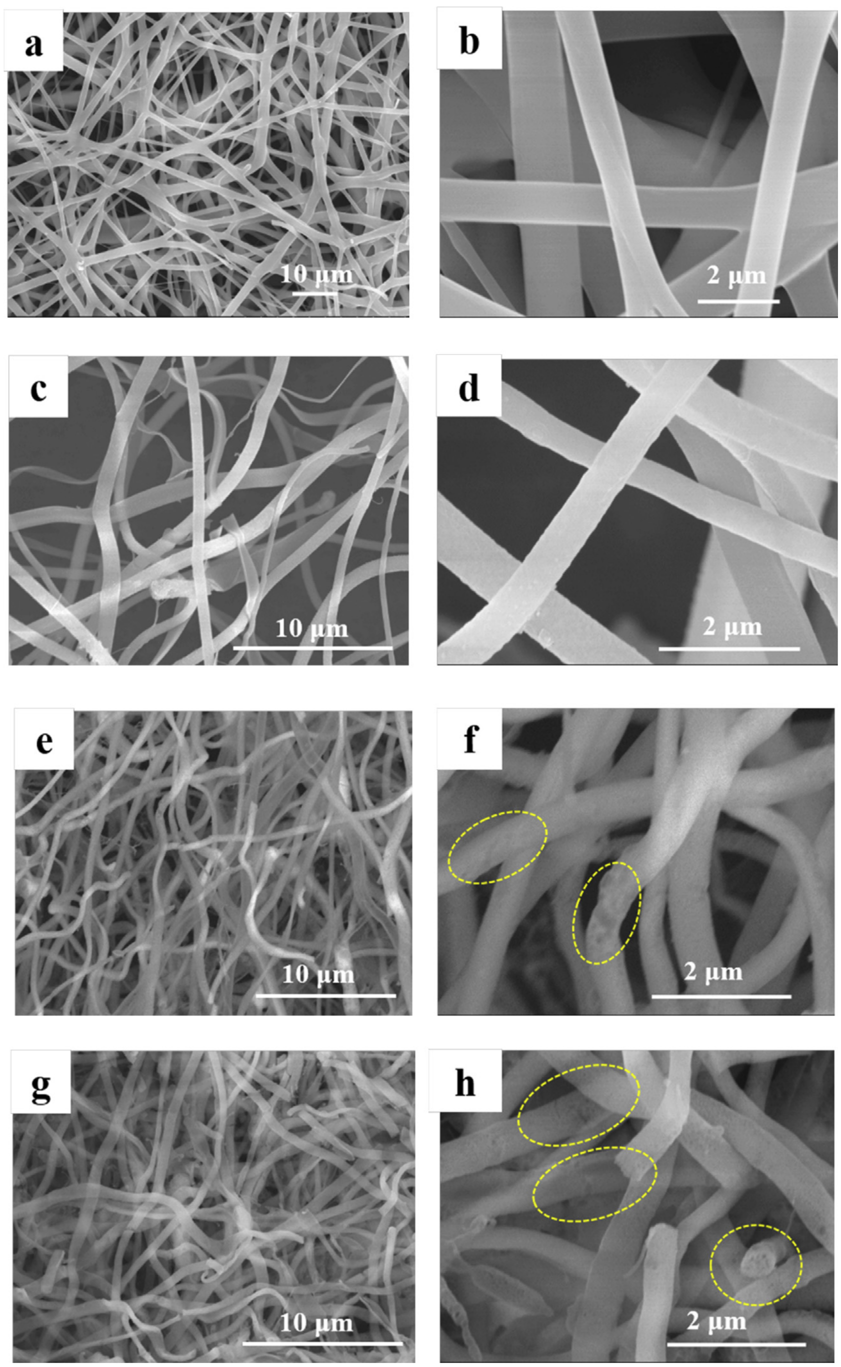

Fig. 2. SEM images (a, b) of precursor fibres, calcinations at 550 °C (c, d), 850 °C (e, f), 1000 °C (g, h).