Effect of Ball-milling Time on Particle Size of Ca$_3$Co$_4$O$_{9+\delta}$

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ABSTRACT

Thermoelectric (TE) materials can directly convert heat to electricity, or vice versa. The misfit-layered Ca$_3$Co$_4$O$_{9+\delta}$ is one of the most promising TE oxide materials, due to its high figure-of-merit (ZT) close to 1.0. In this study, polycrystalline Ca$_3$Co$_4$O$_{9+\delta}$ ceramics were prepared by a simple, thermal, hydro-decomposition method. The influence of ball-milling time on particle size was investigated. The ball-milling process used tungsten carbide balls with a diameter of 1.6 mm, a ball-per-powder ratio of 10:1, rotating speed of 300 rpm, milling time of 2.5 - 20 h and acetone as the dispersion media. The crystal structure and crystallite size were characterized by X-ray diffraction. The single phase of every cobaltite sample was obtained. The particle size and morphology were observed by a field emission scanning electron microscope (FESEM). The particle size was observed to be about 1 µm before ball milling, and was reduced down to 200 nm after milling. The ball-milled particles were fabricated to form bulk ceramics using a spark plasma sintering (SPS) technique. However, second phases were found for the bulk ceramics. The Seebeck coefficient, resistivity and thermal conductivity of the milled sample was higher than that of the unmilled sample. The highest ZT values of the unmilled and milled samples were 0.11 and 0.10, respectively, at 773 K.

Keywords: Ca$_3$Co$_4$O$_9$, Ball mill, Thermoelectric, Thermal hydro-decomposition

INTRODUCTION

Thermoelectric (TE) materials can directly convert heat to electricity, or vice versa. Recently, many researchers have been attracted to TE materials, because they are noiseless, have no moving parts and are environmentally friendly. Several kinds of TE materials, including alloys, skutterudite and oxides have been investigated (Koumoto et al., 2006; Tritt and Subramanian, 2006; Ohta et al. 2008; Snyder and Toberer, 2008). Thermoelectric efficiency is defined