The Effect of Sintering Temperature on Thermoelectric Property of Higher Manganese Silicide

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Abstract

The Higher Manganese Silicide (HMS) was synthesized by solid state reaction and hot pressing. The various sintering temperature was started from 1123 K to 1223 K. The crystal structure and thermoelectric properties of samples were measured. The dimensionless figure of merit (ZT) was calculated from thermoelectric properties. The tetragonal structure of $MnSi_{1.75}$ was confirmed by X-ray diffraction (XRD). The Seebeck coefficient and Electrical resistivity are decreases, while the thermal conductivity increase when increasing sintering temperature. The maximum ZT of $MnSi_{1.75}$ was found in 1223 K of sintering temperature about 0.23 at 473 K.

KEYWORDS: Higher Manganese Silicide; Thermoelectric; Hot press

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Introduction

Thermoelectric materials have been used for alternative energy wherewith it can convert heat into electricity. However, the efficiency of thermoelectric material is limited for a wide variety of applications. The efficiency of the thermoelectric materials is defined by dimensionless figure of merit, $ZT = (S^2/\rho\kappa)T$, S is theSeebeck coefficient, ρ is the electrical resistivity, κ is thermal conductivities, and T is the absolute temperature. The Higher Manganese Silicide (HMS) was candidate for middle temperature of thermoelectric application due to the HMS showed high ZT in temperature ranges of 673 – 973 K. Recently, the undoped HMS was reported the ZT about 0.4 – 0.7 range by mechanical alloying and pulse discharge sintering [1], spark plasma sintering method [2, 3], hot press [4, 5], etc. In this work, has the objective for prepare the HMS by hot press method with various the sintering temperature from 1123 K to 1223 K to study the impact on thermoelectric properties.

Materials and Methods

The Higher Manganese Silicide was synthesized by solid state reaction and hot press method. Mn (99%, Aldrich) and Si (99.9%, Aldrich) were used raw materials. The raw materials were weighed in atomic ratio and mixed by ball milling for 2 h. The powder were placed in the alumina crucible and calcined in quartz tube furnace at 1073 K for 1 h in Ar atmosphere. The calcined powder were pressed in graphite mold (ø20 mm) and heated in temperature 1123 – 1223 K under pressure 33 MPa for 1 h in Ar atmosphere. The pellets were cut in size of 10×10×1 mm^3 and 3×3×15 mm^2 for crystal structure analysis and thermoelectric property measurement, respectively.

The X-ray diffraction (XRD; Shimadzu 6100, Japan) was used for crystal structure characterization. The CuKα radiation at 40 kV, 30 mA and a scanning speed of 5°/min at 2θ steps of 0.02° were setups for XRD condition. The thermoelectric properties include Seebeck coefficient, electrical resistivity and thermal conductivity were measured by steady state method [6] at temperature ranges of 323 – 473 K.

Results and Discussion

The powder XRD patterns of all samples are given in Fig. 1. The result of XRD show the main crystalline phase is $Mn_{27}Si_{47}$ with tetragonal structure (space group P - 4n2) and agree with PDF Number 00-026-1251. In addition, the common impurity phase MnSi was found for all sintering temperature. The 3×3×15 mm^3 HMS pellets were set up in the copper probe for Seebeck coefficient and electrical resistivity measurement and show the result in Fig. 2 and 3, respectively.

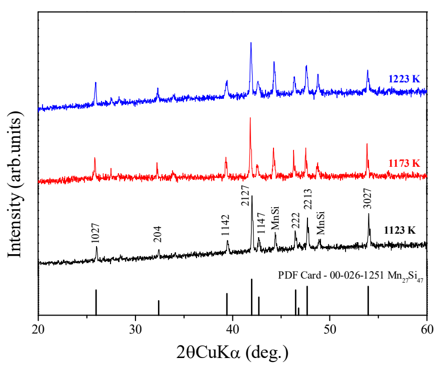

Fig. 1 XRD pattern of $MnSi_{1.75}$ as sintering temperature 1123 K, 1173 K and 1223 K

The Seebeck coefficient of all samples are positive value indicate that *p*-type thermoelectric material and decreases when sintering temperature increasing. The increase of S value with temperature indicate semiconductor behavior. The maximum of S value was found in 1123 K sintering sample about 201 μV K^{-1} at 473 K.

The higher sintering temperature can reduce electrical resistivity which the 1223 K sample shows the lowest value about 0.5 mΩ cm at 473 K. The electrical resistivity of all samples increases with temperature increase.

Fig. 4 shows the variation of the power factor ($S^2\rho$) in function of temperature for sintered samples. The power factor shows evolutions of the electrical conductivity and Seebeck coefficient in function of temperature. The 1123 K and 1173 K of sintering samples are small increases while 1223 K sintering sample shows the large increase with temperature. The maximum $S^2\rho$ = 3.02 mW m^{-1} K^{-2} is observed for the 1223 K sintering sample.

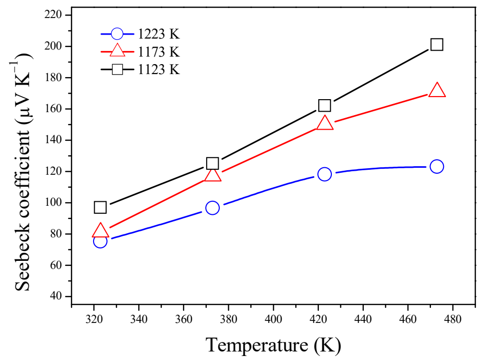

Fig. 2 Seebeck coefficient of $MnSi_{1.75}$ as sintering temperature 1123 K, 1173 K and 1223 K depend on temperature.

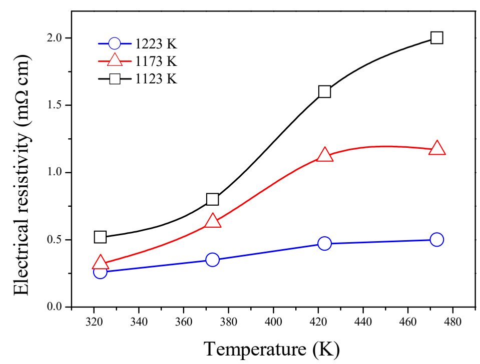

Fig. 3 Electrical resistivity of $MnSi_{1.75}$ as sintering temperature 1123 K, 1173 K and 1223 K depend on temperature

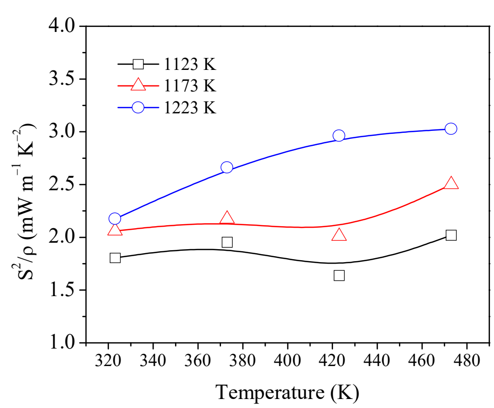

Fig. 4 The power factor of $MnSi_{1.75}$ as sintering temperature 1123 K, 1173 K and 1223 K depend on temperature

The thermal conductivity of sintered samples as a function of temperature is shown in Fig. 5. The thermal conductivity increases with sintering temperature. The lowest κ = 4.79 Wm^{-1} K^{-1} is observed for the 1123 K sintering sample.

Fig. 6 shows the variation of the dimensionless figure of merit in function of temperature for sintered samples. The ZT of 1223 K sample shows the highest value about 0.23 at 473 K due to shows high S and low σ although highest κ.

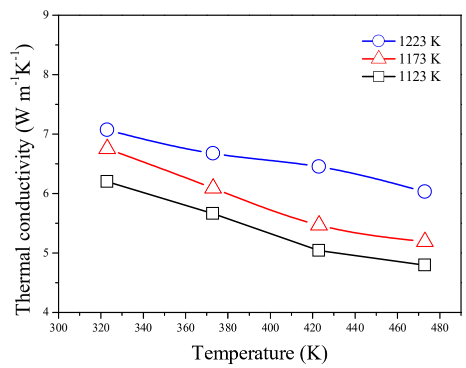

Fig. 5 Thermal coductivity of $MnSi_{1.75}$ as sintering temperature 1123 K, 1173 K and 1223 K depend on temperature

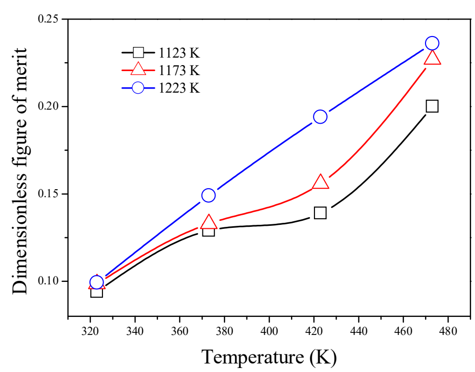

Fig. 6 Dimension less figure of merit of $MnSi_{1.75}$ as sintering temperature 1123 K (black line), 1173 K (red line) and 1223 K (blue line) depend on temperature

Conclusion

The synthesis of $MnSi_{1.75}$ was completed by hot press method. The various sintering temperature was affected to thermoelectric properties by means of high sintering temperature render to decrease S and ρ but increase κ. The maximum power factor is observed in 1223 K sintering sample about 3.02 mW m^{-1} K^{-2} at 473 K. The highest sintering temperature shows highest ZT about 0.23 at 473 K.

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