Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-012-2211-6

Effects of Ni, Pd, and Pt Substitutions on Thermoelectric Properties of CoSi Alloys

HUI SUN,[1,3] XU LU,[2] and DONALD T. MORELLI[1,2,4]

1.—Department of Chemical Engineering and Materials Science, Michigan State University, East Lansing, MI 48824, USA. 2.—Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA. 3.—e-mail: sunhui@egr.msu.edu. 4.—e-mail: dmorelli@egr.msu.edu

Ni-, Pd-, and Pt-substituted CoSi samples have been prepared by an arc melting and annealing procedure. The x-ray diffraction and scanning electron microscopy results show that Ni and Pd are effective *n*-type dopants for CoSi, while Pt is immiscible with CoSi and forms an impurity phase with a possible chemical formula of $PtCoSi_2$. The thermoelectric properties were measured from 80 K to 300 K. For Ni- and Pd-doped samples, the electrical resistivity and Seebeck coefficient decrease simultaneously due to the increasing carrier concentration. For Pt-substituted samples, the electrical resistivity also decreases. However, this reduction is thought to be not due to an increase in carriers but rather to originate from the effect of the Pt-rich impurity phase at the grain boundaries. The Seebeck coefficient is not affected by 1% Pt substitution; however, further increase of the Pt level also causes a decrease in the Seebeck coefficient. The room-temperature power factor is 63 $\mu W\ K^{-2}\ cm^{-1}$ for pure CoSi and 73 $\mu W\ K^{-2}\ cm^{-1}$ for the $Co_{0.99}Pt_{0.01}Si$ sample. Although the thermal conductivity is reduced for both *n*-type-doped and Pt-substituted samples around 80 K, the room-temperature values are still close to that of pure CoSi. As a result, *ZT* of 0.13 is obtained at room temperature for $Co_{0.99}Pt_{0.01}Si$, an 18% increase compared with CoSi.

Key words: CoSi, Ni doping, Pd doping, Pt substitution, impurity phase, thermoelectric properties

INTRODUCTION

Cobalt monosilicide (CoSi) has been reported to be a promising thermoelectric material for near-room-temperature applications.[1] This material shows very low electrical resistivity, on the order of $10^{-4}\ \Omega$ cm, like a metal, but quite large Seebeck coefficient at room temperature.[1–3] Therefore, it exhibits a high room-temperature thermoelectric power factor of tens of $\mu W\ K^{-2}\ cm^{-1}$, comparable to that of state-of-the-art Bi_2Te_3 materials.[4]

In recent decades, researchers have attempted to improve the thermoelectric properties of CoSi by doping. The effects of *p*-type dopants such as Fe on the Co site and Al on the Si site have been studied systematically.[5–8] However, *p*-type doping definitely causes a dramatic increase in the electrical resistivity. As a result, all the *p*-type-doped CoSi alloys show reduced power factors. On the other hand, an *n*-type doping effect has been reported only for Ni-doped CoSi.[6,9] The electrical resistivity is decreased because the replacement of Co by Ni can increase the carrier concentration. Moreover, the study of Sakai et al.[10] shows that the Seebeck coefficient is not decreased significantly for CoSi samples doped by small quantities of Ni. This will likely give rise to an enhanced power factor in the *n*-type-doped CoSi alloys.

The elements in the same group as Ni in the Periodic Table, for example, Pd and Pt, are likely to be *n*-type dopants for CoSi. In this study, we investigated the effects of minute amounts of Ni, Pd, and Pt substitutions on the thermoelectric

(Received June 26, 2012; accepted July 23, 2012; published online August 28, 2012)