Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-013-2476-4

Mechanical Alloying and Spark Plasma Sintering of Higher Manganese Silicides for Thermoelectric Applications

YATIR SADIA,[1,2] LIRON DINNERMAN,[1] and YANIV GELBSTEIN[1]

1.—Department of Materials Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel. 2.—e-mail: yatttir@yahoo.com

The present challenges in the energy crisis require finding new ways to reduce consumption of fossil fuels. Thermoelectrics can help reduce fuel consumption by producing electricity from waste heat. The higher manganese silicides (HMS) have shown promise in this field as inexpensive, nontoxic, and highly stable *p*-type thermoelectric materials. One of the production techniques for HMS is mechanical alloying by ball milling. In this research the effect of the ball-milling duration and speed on the phases produced was studied. Mn and Si powders were milled at speeds of 200 RPM to 800 RPM for 1 h to 7 h. X-ray diffraction (XRD) results of the samples prepared using mechanical alloying show deterioration into the MnSi phase. The sample that underwent 5 h of milling at 800 RPM showed the greatest amount of HMS phase and was subsequently spark plasma sintered. The sample showed insufficient thermoelectric properties ($ZT \approx 0.1$ at 450°C), compared with either solid-state reaction samples showing $ZT \approx 0.4$ or cast samples showing $ZT \approx 0.63$ at 450°C. The reduced ZT values of the mechanically alloyed and spark-plasma-sintered samples were attributed to the high relative amount of MnSi phase. The correlation between the relative amount of MnSi and the transport properties is described in detail.

Key words: Higher manganese silicides, thermoelectric, mechanical alloying, spark plasma sintering

INTRODUCTION

In the past few years, rising fossil fuel prices and greenhouse effects have shifted the world view on renewable energy sources. While various methods of energy conversion exist, one of the most exciting is thermoelectric technology, which satisfies the requirements for long-term stability and low maintenance. This is made possible due to the fact that thermoelectric systems have no moving parts. One of the most important measures of the efficiency of a thermoelectric material is the dimensionless figure of merit (ZT), defined as the square of the Seebeck coefficient times the temperature over the electrical resistivity times the thermal conductivity. While various materials possess desired properties for thermoelectric performance, chalcogenides such as bismuth telluride, germanium telluride, and lead telluride mainly dominated the field in the past. However, while the thermoelectric properties of chalcogenides result in high figure-of-merit values, they have not been successfully introduced into mass production, being limited to rather minor, specialized applications. This has been due to some of their other characteristics, including inferior mechanical properties, toxic lead content, high price of base materials, and high vapor pressure at their peak efficiency temperatures.

In the past few years, several materials have shown thermoelectric properties comparable to those of the chalcogenides. Such families of materials include skutterudites, half-Heuslers, and metal silicides. While all of these material classes have specific merits, metal silicides have attracted much attention due to their low materials cost, high chemical and

(Received June 18, 2012; accepted January 7, 2013; published online February 20, 2013)