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Titanium Disilicide as High-Temperature Contact Material for Thermoelectric Generators

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Thermoelectric devices can be used to capture electric power from waste heat in a variety of applications. The theoretical efficiency rises with the temperature difference across the thermoelectric generator (TEG). Therefore, we have investigated contact materials to maximize the thermal stability of a TEG. A promising candidate is titanium disilicide ($TiSi_2$), which has been well known as a contact material in silicon technology for some time, having low resistivity and thermal stability up to 1150 K. A demonstrator using highly doped silicon as the thermoelectric material has been integrated. A *p*- and an *n*-type wafer were oxidized and bonded. After cutting the wafer into pieces, a 200-nm-thick titanium layer was sputtered onto the edges. After a 750°C rapid thermal annealing step, the TEG legs were connected by a highly conductive $TiSi_2$ layer. A TEG with 12 thermal couples was integrated, and its joint resistance was found to be 4.2 Ω. Hence, we have successfully demonstrated a functional high-temperature contact for TEGs up to at least 900 K. Nevertheless, the actual thermal stability will be even higher. The process could be transfered to other substrates by using amorphous silicon deposited by plasma-enhanced chemical vapor deposition.

Key words: High temperature, $TiSi_2$, thermoelectric module, fabrication, contacts

INTRODUCTION

Thermoelectric devices can be used to capture electric power from waste heat in a variety of applications. Lacking moving parts, the maintenance of such a device is very low. Combining these two facts, such thermoelectric capture of energy can be done at almost no cost. Considering the environment, a thermoelectric generator (TEG) saves primary energy because only waste heat is transferred into electric power. Nevertheless, to earn back their acquisition cost, these devices should be as efficient as possible. The theoretical efficiency rises with the temperature difference across the TEG.[1] Therefore, we have investigated contact materials to maximize the thermal stability of a TEG.

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A promising candidate is titanium disilicide ($TiSi_2$), which has been well known as a contact material in silicon technology for some time, having resistivity of 15 $\mu\Omega$ cm to 35 $\mu\Omega$ cm[2] and thermal stability up to 1150 K.[3] Several other material properties are given in Table I. Temperatures similar to these values exist at the exhaust manifold of ordinary cars and could result in a temperature difference versus cooling water or engine oil of up to 700 K as illustrated in Fig. 1. Instead of an alternator, a TEG might supply the car with electric energy without any loss of engine power.

EXPERIMENTAL PROCEDURES

To test the usability of $TiSi_2$ as a contact material for TEGs, a first demonstrator was built using highly doped silicon as the thermoelectric material (TEM). Although silicon is an inappropriate TEM due to its very high thermal conduction, it was