Thermoelectric properties and crystal structures of Au doped SiC/Si composites

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Abstract: Silicon semiconductor devices such as Power Metal oxide semiconductor field effect transistor (Power MOSFET), Insulated gate bipolar transistor (IGBT) and CPU are the most important devices to give us modern life in the present time. When we use these devices in the electric circuit, the heat removal or the cooling down is one of the most important issues because the silicon device must be the temperature of 423K or lower to keep its function. The heat generation per unit area is the same order of the electric heater in the present devices. There are three different ways to remove the heat from the silicon devices. One is to use the fin connected with the devices, and the second way is to use the fin and fan. The power supply of the fan is necessary. Usually the size of the fin and fan are larger than the size of the device itself, and the costs of the fin and fan are sometimes higher than the cost of the device. The third way is to use the Pletier element, and this is connected with the large fin and fan usually. The Peltier element and the fan need the different dc power supplies for its cooling, individually. Therefore, if we use the Peltier element to cool down the silicon devices, the electric power consumption of the system is increased. This is the one of the reason why the Peltier cooler is not applied for the handy type personal computers. Recently Yamagushi et al. propose the self-cooling device, which does not need to use the additional power circuits because the Peltier cooling is done by its selfcurrent. In this system, the heat flux flow directions of the thermal conduction and the Joule heating are the same for the usual Peltier elements. On the contrary, the direction of the Peltier heat flow is the opposite for the usual Peltier element because of the cooling the high temperature objects. As tabulated in Table 1, it is clear that high Seebeck coefficient, high electrical conductivity and high thermal conductivity are desired in the proposed scheme. In this study, we synthesized SiC/Si and Au doped SiC/Si composites by a conventional solid-state reaction method and studied thermoelectric properties and crystal structures as a function of temperature.

Table 1. The results of electrical resistivity and conductivity, Hall coefficient, carrier concentration, Hall mobility, Seebeck coefficient, power factor, thermal diffusivity, sample density, specific heat and thermal conductivity at room temperature, where PSS is a polysilastyrene.

	$[SiC]_{0.9}[Si]_{0.1}$	$[SiC]_{0.8}[Si]_{0.2}$ + PSS 10%	$[SiC]_{0.8}[Si]_{0.175}[Au]_{0.025}$ + PSS 10%
ρ (10^{-3} Ωcm)	9.97	3.82	**3.36**
σ (1/Ω cm)	100	262	**298**
S (10^{-6} V/K)	109	88.0	92.4
S^2/ρ (10^{-12} W/cmK^2)	1.19	2.03	**2.54**
R_H (10^{-2} cm^3/C)	3.09	1.99	1.93
n (10^{20} /cm^3)	2.02	3.13	3.23
μ (cm^2/Vs)	3.10	5.21	**5.74**
A (g/cm^3)	1.69	**2.10**	**2.17**
B (cm^2/s)	0.32	**0.38**	**0.37**
C (J/gK)	0.68	**0.68**	**0.66**
κ (10^{-3} W/cmK)	366	**537**	**524**