The American Journal of Engineering and Technology
(ISSN – 2689-0984)
Published: December 31, 2020 | **Pages:** 50-54
Doi: https://doi.org/10.37547/tajet/Volume02Issue12-09

IMPACT FACTOR
2020: 5. 32
OCLC - 1121105677

Basic Thermoelectric Properties Of Granulated Silicon With Alkali Metal Atoms

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ABSTRACT

In this study, the basic thermoelectric properties of granulated silicon with alkali metal atoms were studies in the process of temperature change. When analyzing the changes in the Seebeck coefficient (α), electrical conductivity (σ) and thermal conductivity (χ) under the influence of temperature, which are the main thermoelectric parameters.

KEYWORDS

Granular silicon, thermoelectric parameters, impurities, thermoelements, recombination centers.

INTRODUCTION

The thermoelectric property of semiconductor materials is associated with the formation of different energy levels in their forbidden zone, and this property of semiconductor materials is widely used in the creation of thermo elements [1]. According to the analysis of the literature, the main thermoelectric property of a granular semiconductor material depends on the nature of the multilayer heterogeneous medium, consisting of input states or defects in two connected boundary regions. Under the influence of temperature, current and voltage are generate with the formation of electron-hole pairs in a heterogeneous medium. The formation of electron-hole pairs depends on the nature of the initial state and defects in a multilayer heterogeneous medium. The thermoelectric properties of semiconductor materials are explain by parameters such as the Seebeck coefficient (α), electrical

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conductivity (σ) and thermal conductivity (χ). The controllability of these parameters makes it possible to create efficient thermoelectric materials based on granular silicon [1].

MATERIALS AND METHODS

In fig. 1 shows the temperature dependence of the Seebeck coefficient (α). The results show that the Seebeck coefficient decreases exponentially in granular silicon without the addition of alkali metal atoms with increasing temperature. At ~400 K, its value is 500 mkV/K, which is consistent with the results obtained in the study [1]. On the contrary, an increase and decrease in the Seebeck coefficient was observed in granular silicon containing alkali metal atoms. For example, in granulated silicon in which Na atoms are introduced, the Seebeck coefficient increases initially to T≤475 K, is stable in the later stages of temperature increase, in samples with Cz atoms increases to T≤475 K, and then decreases significantly in subsequent stages of temperature increase.

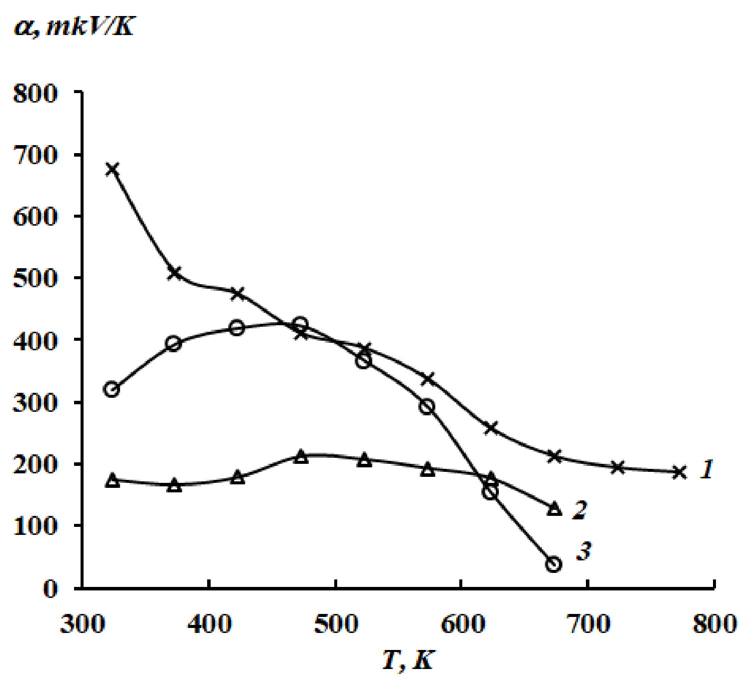

Figure 1. *Temperature dependence of the coefficient of Seebeck: Atoms 1 - Si, 2 - Na, 3 - CZ belong to the inserted granules*

In our opinion, an increase in the Seebeck coefficient with increasing temperature in granular silicon containing alkali metal atoms is counteracted by the alkali metal atoms of the recombination centers, which appear in two neighboring domains of granular silicon (Fig. 2a, 5 region), and leads to an increase in the concentration of electron-hole pairs. The decrease in the Seebeck coefficient can be associated with the formation of the input states of the complex compound Li_x–O_y, Na_x-O_y, K_x-O_y, Cs_x-O_y или Li_x-V_y, Na_x-V_y, K_x-V_y, Cs_x- V_y.

With the formation of complex compounds Li_x–O_y, Na_x-O_y, K_x-O_y, Cs_x-O_y or Li_x-V_y, Na_x-V_y, K_x-V_y, Cs_x- V_y in two connected regions of granular silicon (Fig. 2a, 5 region) atomic the structure of this industry changes, which in turn leads to changes in the electronic state and thermal conductivity of this industry. In this regard, the thermal conductivity of the samples was also investigated.

There are several methods for determining the thermal conductivity, of which the methods of Egor and Disselhorst [2, 3, 4, 5] are widely used in the study of the thermal conductivity of rod-shaped samples.

Knowing the electrical conductivity (σ) of the sample, the voltage drop (U) in the sample and the temperature difference (Δt), the thermal conductivity can be determined by the following expression

$$\chi = \frac{U\sigma}{8\Delta t} \qquad (1)$$

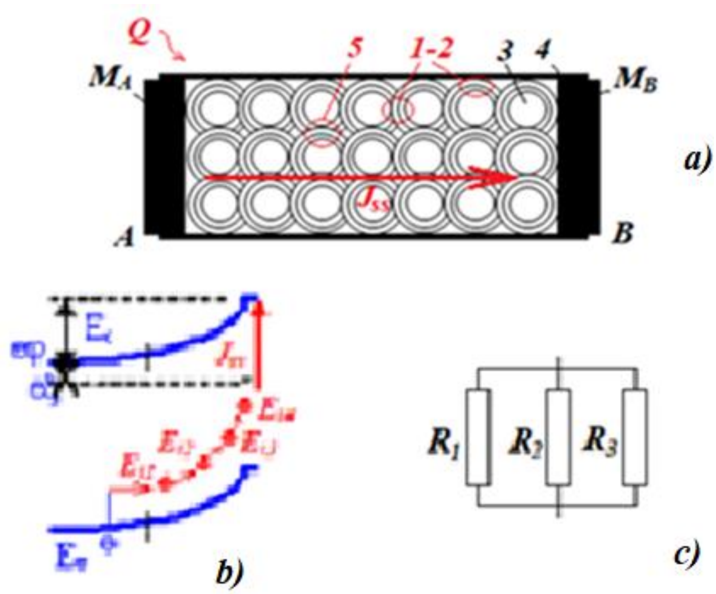

Figure 2. Research methodology and a simplified layout of granules, respectively (a), zone diagram (b), and resistance diagram (c). 1,2,3 - semiconductor powder, 4 - ceramic tube, 5 - contact area of granules located parallel to each other, ohmic contacts in regions *A* and *B*, respectively M_A and M_B. *Q* is the amount of heat transferred.

RESULTS AND DISCUSSION

Figure 3 shows the temperature dependence of thermal conductivity. The results show that with increasing temperature, the thermal conductivity of all samples increases. The value of thermal conductivity at T≤400 *K* ~15 *Vt/mK* in granular silicon without the addition of alkali metal atoms with increasing temperature corresponds to the results obtained in the study [1]. At the later stages of increasing temperature, it varies from ~30÷40 *Vt/mK*. In samples containing alkali metal atoms, an increase in thermal conductivity is observed to T~475 *K*, and then a decrease. For example, in granulated silicon with *Na* atoms to T~475 K, thermal conductivity varies from ~10 *Vt/mK* to ~50 *Vt/mK*, and in samples with *Cz*

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atoms, thermal conductivity varies from ~20 *Vt/mK* дан ~70 *Vt/mK*.

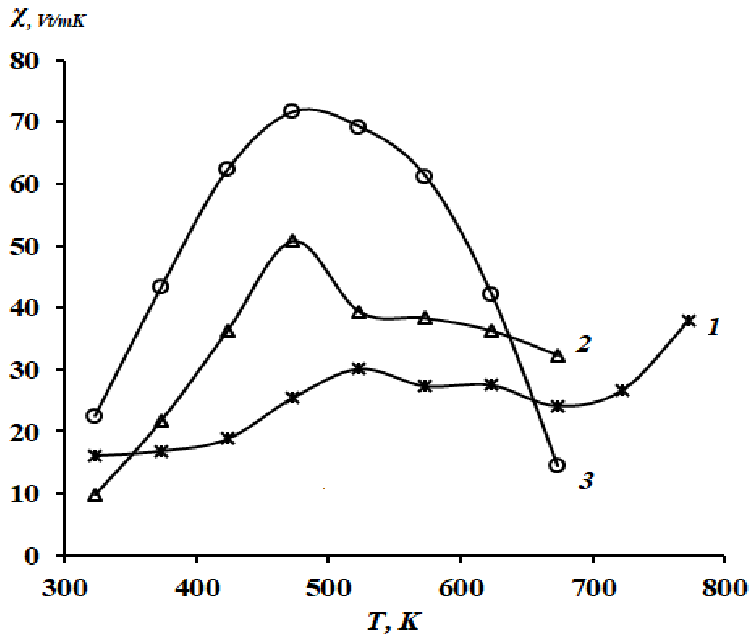

Figure 3. Temperature dependence of thermal conductivity: atoms 1 – Si, 2 – Na, 3 – Cz belong to inserted granules.

It is known that the introduction of various impurities leads to a change in the thermal conductivity of semiconductor materials. For example, if the thermal conductivity of thermoelectric materials obtained by the powder method decreases due to external pressure, the change in its composition due to the introduction of additional impurities can lead to an increase in thermal conductivity [6]. In our case, the introduction of alkali metal atoms into granular silicon leads to an increase in thermal conductivity. As mentioned above, due to the dissociation of alkali metal atoms in two connected areas of granulated silicon (Fig. 2a, 5 region), complex compounds of Li_x–O_y, Na_x-O_y, K_x-O_y, Cs_x-O_y or Li_x-V_y, Na_x-V_y, K_x-V_y, Cs_x-V_y and the atomic structure of this industry varies. This, in turn, can lead to changes in electronic condition and thermal conductivity in industry. It should be note that the effectiveness of thermoelectric materials is directly proportional to the electromotive force and electrical conductivity and inversely proportional to the thermal conductivity. Increased thermal conductivity adversely affects the effectiveness of thermoelectric materials. However, as discussed above, the elimination of defects in two connected areas of alkali metal atoms in granular silicon leads to an increase in the Seebeck coefficient in accordance with the temperature (Fig. 1).

CONCLUSIONS

Thus, the results obtained in the study of the thermoelectric properties of granular silicon are important for obtaining new types of thermoelectric materials that explain physical processes in them. The obtained results and considerations serve to illuminate the physical properties of granulated semiconductors, including the structure of granules, the mechanisms of formation of alkaline metal atoms in the two adjacent areas of granulated silicon, charge transfer processes between them, as well as other kinetic phenomena in micro- and nanoscales.

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