APPLICATION OF ELECTRIC CURRENT IN GROWING SILICON SINGLE CRYSTALS

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Introduction

Application of electric field to silicon semiconductor materials is used to modify the melt convection mode in Czochralski growth configuration [1] and to control of structures at the surface of crystal [2]. It is very important to study the temperature distribution of silicon semi-conduction material to understand the electric current-induced Joule heating phenomena. In this work, we have developed the mathematical model to describe the Joule heating phenomena in silicon.

Experiment

Fig. 1 shows the schematic of experimental apparatus to study Joule heating effect in silicon materials. The silicon crystal samples are prepared by Czochralski process. The length and diameter of silicon samples are 11 cm and 0.5 cm, respectively. The specific resistively of silicon crystal is 12 $\Omega \cdot$cm at room temperature and boron is used to control the electric properties of intrinsic silicon semiconductor.

The experimental results to study electric current-induced Joule heating phenomena were shown in Fig. 2. As the electric current (I) is increased, the applied voltage in closed circuit is decreased. At first glance, these results do not follow Ohm's law. The mathematical model to describe these nonlinear phenomena shown in Fig. 2 was developed and solved numerically.

Results and Discussion

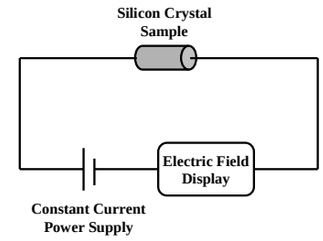
The temperature in the silicon crystal, the electric current and applied voltage in closed circuit were obtained by applying the numerical method to the mathematical model for the electric current-induced Joule heating phenomena at atmospheric environment. We investigated the heat transfer in the silicon semiconductor and the effects of electric current on the stabilized applied voltage and the temperature of silicon crystal. The results of a sample case are shown in Fig. 3. In this case, the set value of electric current is 5 A and the limit value of applied voltage is 300 Volt.

Conclusions

The numerical calculations give a detailed picture of the temperature in silicon crystal and electric filed in the closed circuit. The reproduction of nonlinear phenomena - the decrease of stabilized applied voltage in closed circuit with the electric current - confirms that the mathematical model is well constructed.

References

[1] M. Watanabe, M. Eguchi, W. Wang, T. Hibiya and S. Kuragaki, *J.Crystal Growth*, **237-239**, 1657 (2002)
[2] T. Sameshima, Y. Kaneko and N. Andoh, *J. Non-Cryst. Solids*, **299-302**, 746 (2002)



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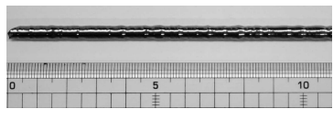

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Fig. 1. (a) Schematic of experimental apparatus for electric current-induced Joule heating phenomena and (b) The photography of silicon crystal sample

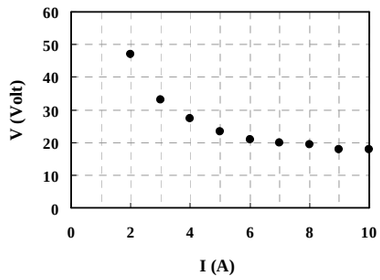
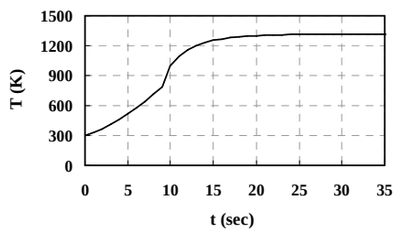


Fig. 2. Applied voltage (V) as a function of electric current (I)



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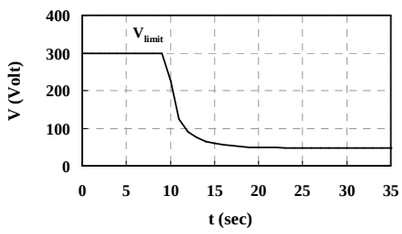

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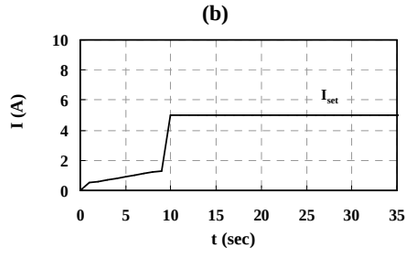

(c)

Fig. 3. (a) Temperature of silicon crystal, (b) Applied voltage and (c) Electric current in closed loop for the sample case