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INFLUENCE OF TAKING OF GAS-VAPOR MIXTURE FROM CHAMBER OF GROWING OF SINGLE-CRYSTALS OF SILICON ON RELIABILITY GRAPHITE RIGGING

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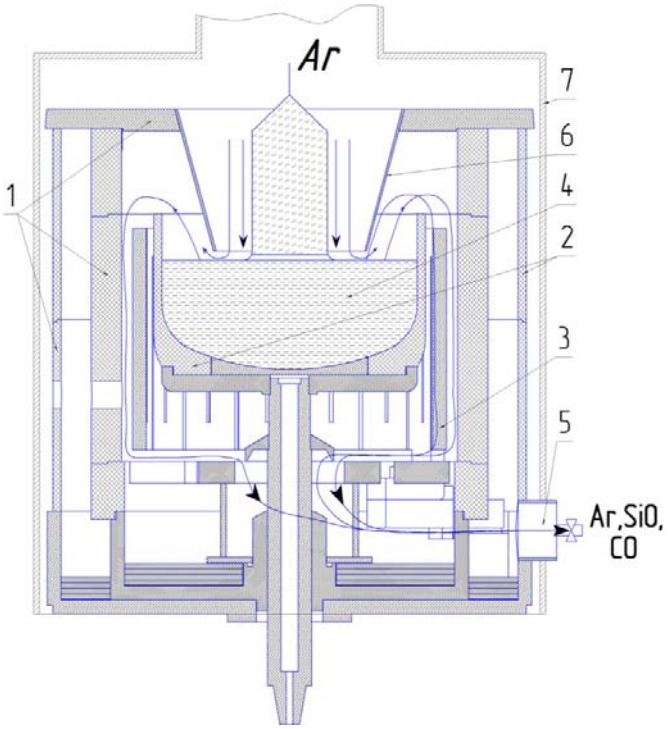
The influence of place to gas-vapor mixture from the chamber of growing silicon single crystals by Czochralskij method on the reliability of graphite equipment has been given. The analysis results of the fulfilled experiments shows that the placement of the vacuum discharge in chamber growing renders influence on resistance of the graphite tooling and the quality of the grown single crystals.

Key words: silicon, single crystal, growing, Czochralskij method, furnace, argon, admixtures

Introduction. Single-crystal silicon is basic material for making of power electronics devices: heavy diodes, thyristors, transistors, integrated circuits, - which are used at the transmission of electric power on large distances, in powerful productions, for example, in metallurgical and chemical production, and also in the systems of electric power supply for aggregates [1].

Growing of single-crystals of silicon is executed by Czochralskij method from quartz crucible with the use of the special furnace, presented on a fig. 1 and consisting of graphite heater and graphite screening [2,3].

At growing of single-crystals in the environment of argon there it is formation of gas-vapor mixture of silicon monoxide *SiO*, argon and carbon monoxide *CO*, and also other volatile admixtures, being in silicon fusion [1].



1 is screening; 2 is crucible and block; 3 is a heater; 4 is silicon fusion; 5 is taking of das-vapor mixture;

6 is a well; 7 is a chamber (corps) of furnace
Figure 1 is «Redmet»furnace with a bottom vacuum taking

The source of oxygen in the single-crystals of silicon is considered the quartz crucible is walls of crucible which contact with silicon fusion at process of growing with formation of atomic oxygen, passing to the crystallizable single-crystal [4]. Intensity of dissolution of crucible and transition of oxygen to fusion is in straight proportional dependence on the area of contiguity of fusion and crucible 2, and also depends on the state of its internal surface [5].

Dissolution of quartz in silicon fusion takes place with formation of its monoxide *SiO* on a reaction [4]:

$$SiO_{2(тв)} + Si_{(ж)} \Rightarrow 2SiO_{(г)} \ . \quad (1)$$

As a result of chemical reaction between the silicon monoxide *SiO* and graphite elements of accessory of furnace appear carbon monoxide *CO* [2], silicon carbide *SiC* and free silicon *Si*.

$$C_{(тв)} + SiO_{(г)} \Leftrightarrow Si_{(тв)} + CO_{(г)} \ ; \quad (2)$$

$$2C_{(тв)} + SiO_{(г)} \Leftrightarrow SiC_{(тв)} + CO_{(г)} \ . \quad (3)$$

Basic source of carbon serves monoxide carbon *CO*, which appears as a result of co-operation for monoxide silicon, in the grown crystals, on a reaction (2), with the graphite of heater elements, supports for crucible and graphite screening, applied for creation of optimal heat conditions of growing [3]. The carbon monoxide *CO* appears also as a result of co-operation of oxygen, acting into a chamber through compressions from an environment, and graphite of heater elements and graphite screening.

An appearing carbon enters in area of silicon crystallization and as an admixture crystallized together with silicon.

During crystallization there is a satiation of the grown silicon single-crystal by admixtures and formation in its defects that entails the decline of its high-quality descriptions.

As be obvious from a fig. 1, evacuation of gas stream is executed in the lower end of chamber, below than elements of furnace. Gas-vapor mixture consisting of silicon monoxide, argon and carbon oxide walking away from fusion is sent through the hot (with a temperature 800…1500 °C) furnace elements, here aggressive combined cycle streams enter into co-operating with the graphite elements of knot and result in contamination of atmosphere for chamber growing of single-crystals.

Such situation after completion to the operation of growing of single-crystals requires implementation of cleaning of system and graphite accessory, and before subsequent realizations of this process are degassing of elements of thermal knot [1].

Problem formulation. A task hired is a study of influence of place of location of taking of gas-vapor mixture from the chamber of growing of single-crystals on reliability of graphite heater and accessory of furnace.

Basic part of researches. In the process of experiments it was set that the degree of change for geometry of graphite heater (thinning of making heater) increases with growth of quantity of technological processes for growing of single-crystals. As a result, it is accompanied by the change of size electric resistance for heater and, ac-

cording to its thermal descriptions. The change of electric resistance R for elements of heater is estimated by dependence

$$R = \rho \cdot \frac{\ell}{S} \ , \tag{4}$$

where R is resistance of heater material, Ohm, ℓ, S are length, mm, and area of cross-sectional, mm^2, heater accordingly.

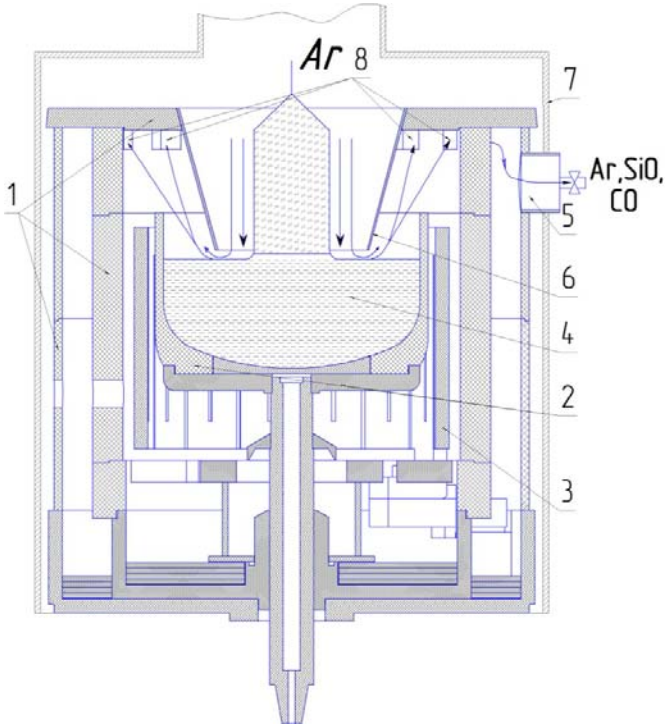
The increase of electric resistance for elements of heater renders substantial influence on power P, consumable by a heater for creation of necessary temperature in the area of single-crystal crystallization.

$$P = I^2 \cdot R \ , \tag{5}$$

where I is a current, given on heater, A.

In this connection for maintenance of constant size of power it is necessary to reduce the size of current. It results in the increase voltage and by the increase of burden on a feed-in transformer that is accompanied by his exit from normal mode of work and violation of the technological modes of growing of single-crystals.

For the removal of violation of geometrical and electric descriptions of thermal knot we are test the change of position of place of taking of gas-vapor mixture from the chamber for growing of single-crystals by its transfer from the lower end of chamber in an area, located at the level of cover for furnace, like a decision, described in work [7] (fig. 2). Such location of place of the gas taking provides the change of streamline for stream of gas-vapor mixture and considerable reduction of its participating in reactions with material of furnace.



1 is screening; 2 is crucible and block; 3 is a heater; 4 is silicon fusion; 5 is taking of gas-vapor mixture; 6 is a well; 7 are openings for taking of gas-vapor mixture; 8 is a chamber (corps) of furnace
Figure 2 is «Redmet» furnace with a lower oven vacuum taking

The serve of argon to fusion in the chamber for growing of single-crystal although a well (fig. 2) provides the backing-off for gas-vapor mixture, appearing as a

result of co-operating of silicon fusion with quartz crucible 2 and by a heater 3. For the effective backing-off of gas-vapor mixture in the lateral screen of well the special openings are executed 7.

On a fig. 3 and fig. 4 dependences of wear and general resistance of graphite heater on the quantity of technological processes of growing has been presented

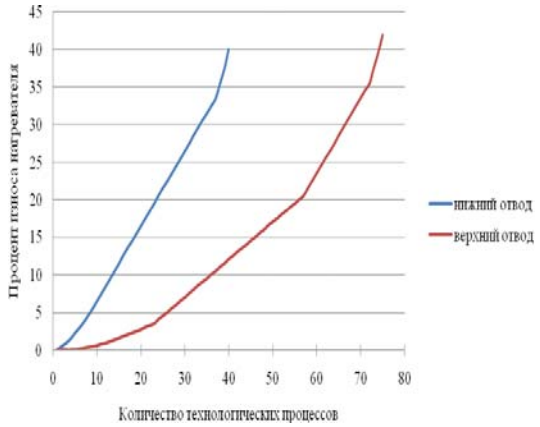


Figure 3 is Dependence of wear heater on the quantiy of processes

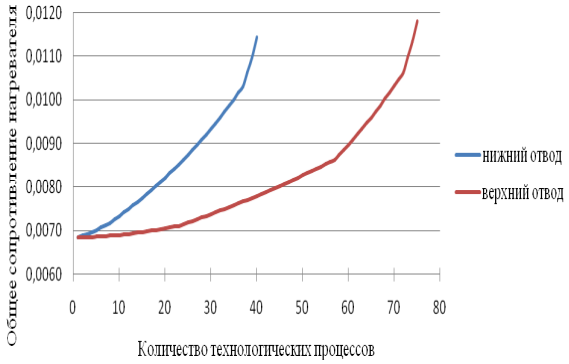


Figure 4 is Dependence of change resistance of heater on the quantity of processes

As be obvious from figures, the change of place of taking for gas-vapor mixture from the chamber for growing of single-crystals considerably promotes the resource of work of graphite heater (fig. 3), here its electric resistance (fig. 4) is saved long time, that provides constancy of the technological modes of growing and producibility of electro physics descriptions for single-crystals.

Conclusions. The results of the carried out researches allowed to set that the change for location of place of taking for gas-vapor mixture from the growing chamber of silicon single-crystal assists the increase of life cycle for graphite heater and maintenance of its electric resistance. Thus possibility of maintenance for constancy of the technological modes of growing of single-crystals is shown.

REFERENCES

1. **Фалькевич, Э. С.** Технология полупроводникового кремния [Текст]: монография / Э. С. Фалькевич, Э. О. Пульнер, И. Ф. Червоный и др.; под ред. Э. С. Фалькевича. – М. : Металлургия, 1992. – 408 с. – Библиогр.: с. 399-407. – 1170 экз. – ISBN 5-229-00740-0.
2. H. Föll Silicon Crystal Growth and Wafer Production Single Crystal Growth [Електронний ресурс]. – Режим доступу: http://www.tf.uni-kiel.de/matwis/amat/elmat_en/kap_6/backbone/ r6_1_2.html.
3. **Stefano, Meroli**. Two growth techniques for mono-crystalline silicon: Czochralski vs Float Zone. [Електронний ресурс]. – Режим доступу: http://meroli.web.cern.ch/meroli/Lecture_ silicon_floatzone_czochralski.html.
4. **Бабич, В. М.** Кисень в монокристалах кремнію [Текст] / В. М. Бабич, Н. И. Блецкан, Е. Ф. Венгер. – Київ : Інтерпрес ЛТД, 1997. – 239 с. – Бібліогр.: с. 223-239. – 1000 прим. – ISBN 966-501-021-2.
5. **Нашельский, А. Я.** Производство полупроводниковых материалов [Текст]: учеб. пособие / А. Я. Нашельский. – М. : Металлургия, 1989. – 272 с. – Библиогр.: с. 270. – 5820 экз. – ISBN 5-229-00247-6.

6. **O'Mara, W. C.** Handbook of semiconductor silicon technology [Text]: W. C. O'Mara, R. E. Herring, L. P. Hunt. – Mill Road, Park Ridge, New Jersey, 1990. – 814 p. – References: p. 787-788. – 1000 copies. – ISBN 0-8155-1237-6.
7. **Пат. 2241079 Рос. Федерация: МПК C30 B 15/00, C 30 B 15/14, C 30 B 29/06.** Устройство для выращивания монокристалла кремния из расплава [Текст] / С. В. Алексеев; заявитель и патентообладатель Федеральное государственное унитарное предприятие «Научно-исследовательский институт Научно-производственное объединение «Луч». – 2003117511/15; заявл. 17.06.2003; опубл. 27.11.2004.