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ELECTRO-IMPULSIVE CRUSHING OF HIGH-CLEAN CRYSTALLINE SILICON IN WATER ENVIRONMENT

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Experimental researches are executed and the process of crushing of high-clean silicon is realized without the use of contaminating processes of cleaving on mechanical presses and tempering in water from a temperature 600 °C. There is worked out pilot plant, in which crushing of silicon takes place under the action of resilient wave in water, created by a powerful electric discharge-cathode directed streamer. The electro-hydraulic crushing will allow to shorten the losses of silicon as shallow factions, will reduce the volumes of the used etching solutions and will improve ecology.
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The large-scale production of silicon of semiconductor cleanness, besides basic technological operations on the making of poly- and single-crystals, includes the row of operations on their treatment. Foremost, it is operations on growing (crushing, cutting) and cleaning of surface of silicon shallow by the methods of chemical etching. The transferred operations are intended both for producing of the certificated end products and for the internal use - in the processes of the further metallurgical processing of raw material.

Presently growing of bolts of polycrystalline silicon shallow is produced at their cleaving by means of mechanical presses with the further sorting of pieces in size and sifting out of shallow factions (less than 3-5 mm. The most transferred operations are mechanized; however removing contamination of silicon by the admixtures of metals as a result of crushing is impossible. Therefore by a subsequent operation, before shipping of the end products, there is chemical treatment of pieces (etching) in mixture of the concentrated acids (*HF* - 49 %, HNO_3 - 70 %) with the subsequent careful washing in the deionized water. Taking into account the necessity of observance of conditions of the rationed expense and multipleness of the use of one portion of etchant on one kilogram of silicon, successive washings of surface of silicon, an enterprise is put before the task of utilization of large volumes of etchant solutions and cleaning of water drains.

Simplification of this task is possible, if to use heating of silicon large pieces to the temperatures 400-600 °C the subsequent operations of tempering of them in the deionized water, drying and divisions on faction.

This technology, worked out by a company «*PVA TePla*» (Germany) allows to decrease both contamination of silicon by metallic admixtures at crushing and volumes of the used and reutilizable etchant solutions, however decides the problem of losses of silicon as shallow factions, quantity and largeness of which it is enough difficult yields to adjusting. For an economy, the row of enterprises tries to use appearing shallow factions as addition to the raw material loading in crucible during realiza-

tion of processes of growing on Chokhralskij method. However a similar measure results in contamination of fusion, transition of them, out-of-control admixtures in a growing single-crystal, serves as reason of appearance of point defects of structure, to their further transformation in more large imperfect educations, and also can result in the emergency formation of cracks in quartz crucible and channel of fusion.

To realize the high-clean process of crushing of silicon, reduce its power-intensity, provide the set factious composition of charge and working out ecological problems is possible at the use of new technologies on the basis of electro physics methods of treatment of materials. The row of processes growing which can be used depending on hardness shallow, level of internal resilient tensions and cracking of material is worked out [1,2].

In particular, the method of electro-bit destruction is worked out in SRI of the Impulsive processes and technologies of NASU. By an affecting instrument on material in this method there are shock waves, formed by a high-voltage discharge in a liquid. The density of energy in the channel of discharge is comparable with the volume density of energy of explosives. In the moment of digit the wave of pressure strikes on the surface of material, reflected partly, stretches material, and is reason of formation of "slabbing" cracks, swelling of surface and destruction. Efficiency of destruction from subsequent digits depends on a quantity and depth of appearing penetrating cracks and can be expected. Necessary frequency of discharges is set from requirements to grain-size distribution. The productive apparatus of crushing must provide the power mode with energy of discharge ~ 1,25 kJoul [3].

The considerable diminishing of specific energy costs at the insignificant sizes of equipment and capital costs impulsive electro-bit technology can provide [4]. At an action into the volume of liquid, belong in a flask, specially formed impulsive electric digit round the area of its formation there are hydraulic hyperpessures, able to accomplish useful mechanical work.

The researches conducted in the real work showed that in the process of the electro-impulsive crushing between electrodes there is the ionized channel, spreading to the electrodes (streamer). Cathode directed streamer appears at substantially less tension of the field, therefore his application technically more perspective. The presence of the ionized channel assists conversion of water in the state of very resilient body and creation of area of destruction.

The calculations conducted in the real work showed that at voltage, attached to the discharge chamber U = 49 kV, the initiation streamer condition is executed. Thus a discharge interval makes d = 2.45 sm. For realization of process of the impulsive crushing providing of mean value of the field tension is needed in a bit interval ~ 20 kV/sm, continuance of front of the formed impulse of high voltage of 100-200 ns and frequencies of the following of impulses are 0.5-2.0 Hertzs. The analysis of charts and methods of forming of high-voltage impulses showed efficiency of principle of inductive store of energy in combination with powerful semiconductor chopperes (SOS-diodes).

For realization of the technological apparatus with the use of streamer discharge it is necessary to create the reshapers of high-voltage impulses with specific parameters. During realization of the real researches the reshaper of high-voltage im-

pulses, in which due to the use of diode with properties of sharp renewal forming of going out impulses is arrived at with tension, considerably greater, is worked out, than voltage of power source.

The chart of the worked out reshape contains a bridge from the semiconductor keys and batching condenser which is plugged in the diagonal of bridge. An inductive reactor is included between the negative pole of entrance tension and output of semiconductor bridge. An output condenser is connected through a diode to the inductive reactor. A diode is connected between an output condenser and negative pole of source of entrance tension. Output tension is taken off from a diode, possessing properties sharp renewal (for example, SOS-diode).

Conclusion. As a result of the use of method of the electro-hydraulic crushing and worked out apparatus it is possible to realize dust-free destruction of silicon, provide the required size of pieces (due to adjusting of amplitude and frequency of the following of impulses of tension), substantially to shorten the losses of silicon as shallow (less than 2.0 mm) factions. It is shown that necessary for crushing of silicon a shock wave can be created by a powerful electric digit in the deionized water. Possibly substantial, as compared to the process of the mechanical crushing, decline of volumes of the used acids for cleaning of surface of silicon, decline of expenses on procedure of chemical treatment. Possibility of realization of crushing of silicon in the deionized water in a prospect will allow practically fully to give up the use of acidization, that will allow to remove the extrass of harmful matters and to improve ecology.

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