PRODUCTION OF SOLAR SILICON FOR MANUFACTURING PHOTOELECTRIC CONVERTERS AS A WAY TO INCREASE THE ECONOMIC POTENTIAL OF THE COUNTRY

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Abstract: The paper describes the problems of producing and purifying of silicon for making photoelectric converters. Modern advances in silicon production for photoelectric transducers are also described.

Introduction

In our time, the humanity needs more and more energy, the need for it is increasing every year. At the same time, reserves of traditional natural fuel (oil, coal, gas, etc.) are exhaustible. According to some researches by 2020 fossil fuel reserves will be able to satisfy the world's energy only partially. Stocks of nuclear fuel, namely uranium and thorium, are also exhaustible. Energy needs can be satisfied by renewable sources. Today, renewable energy sources are attracting more and more attention of both ordinary people and governments of many countries and international organizations. The major source of renewable is energy of the sun which can be obtained with the help of photovoltaic cells. This way of solving the energy problem is very attractive due to its cleanliness, using virtually inexhaustible source of energy and to the absence of long-term cycles of heating and rotating machinery. The main component of solar photoelectric converters is silicon, the production of which is a complex and expensive task.

The goal of our work is to identify the solar silicon production problems and possible solutions.

Photovoltaic power plants are our future

The most promising type of solar energy conversion into electricity are photovoltaic power plants with elements based on silicon, whose efficiency reaches 15%.However, such stations will be profitable only when there is technology and materials which can reduce energy costs 2 to 3 times.The main obstacle in this way is currently high cost of producing a polycrystalline silicon semiconductor with the aid of traditional methods.

Many countries are actively working on development of the production of solar energy converters, which are based on silicon "solar" quality as a material favorable for photoelectric converters with specific physico-chemical properties and with a high level of modern technology used for its production. But the development in this direction is constrained by the high cost of a unit energy produced by trichlorosilane method in comparison with conventional sources.

Silicon is the second most abundant element in the earth's crust. According to different information sources, silicon content in the earth's crust is 27,6-29,5%.

Benefits of Solar Panels

One of the advantages of using solar panels is that photovoltaic power plants are environmentally friendly and easy to build, thanks to their modular design. In addition, the photoelectric converters are characterized by high reliability (at present they are the source of energy for virtually all satellites on the Earth's orbit because they work without breakdowns and require almost no maintenance), low operating costs (due to the absence of moving parts photoelectric converters do not require special care), environmental friendliness (fuel is no burnt when they work), modularity (owing to this property, photoelectric converters can achieve very different sizes, depending on the energy requirements), long life (up to 30 years), low construction costs (usually photoelectric converters are built close to the consumer, that is there is no need to pull the power lines over long distances or to buy transformers),and of course it should be noted that photoelectric converters are independent of changes in energy prices.

How polycrystalline semiconductor silicon is made

There are two main ways of making high (semiconductor) purity silicon. They are using trichlorosilane and silane.

When obtaining silicon from silane threechlorine

$SiHCl_3 + H_2 \rightarrow Si+3HCl$

silicon tetrachloride and hydrogen chloride are formed, which leads to a decrease in silicon yield, penetration of harmful impurities, which are formed with the corrosion of chamber walls and other parts of the installation, into the silicon and causes environmental problems. Therefore, it is difficult to obtain ultrahigh purity silicon from trichlorosilane.

The use of monosilane technology has several advantages:

1. thermal decomposition of monosilane takes place at a relatively low temperature (about 850°C instead of 1100 ° C for trichlorosilane) and lower energy consumption;
2. clearing monosilane from most harmful impurities ceteris paribus is more efficient because of the significant differences in physical and chemical properties of monosilane and other compounds;
3. together with the silicon there is a salable product which is itself a mixture of monosilane, which is needed for the thin film technology of manufacturing semiconductor products, including making solar cells of amorphous silicon.

However, this technology has certain disadvantages. So purification of monosilane by distillation at a low temperature requires cooling it with liquid nitrogen and helium, which greatly increases the cost of silicon. Furthermore, the known methods for producing monosilane are quite complicated in comparison with trichlorosilane, which is the cause of high cost of high purity monosilane in the semiconductor industry.

For this reason monosilane is used to a limited extent only for obtaining polycrystalline silicon of super high purity. Its reprocessing into single-crystal silicon is carried out by floating zone melting method.

To reduce the cost of monosilane and high purity silicon obtained from it an intensive search for new and effective ways is going on. Currently known methods include:

1. Method of Komatsu firm (Japan) provides atsedoliz magnesium silicide (Mg_2Si) from silicon metal and magnesium metal, its decomposition by ammonium chloride in liquid ammonia with the release of monosilane in the following reactions:

1) $Si + 2Mg = Mg_2Si + Q$, 2) $Mg_2Si + 4NH_4Cl = SiH_4 + 2MgCl_2 + 4NH_3$.

2. Disproportionation reaction is conducted with the purified trichlorosilane on the catalyst with obtaining thermally decomposed monosilane (Method firm Union Carbide USA) to polycrystalline silicon.

$4SiHCl_3 = 2SiH_2Cl_2 + 2SiCl_4$

$2SiH_2Cl_2 = SiCl_4 + SiH_4$

$SiH_4=Si+2H_2$ (decomposition occurs at t=1050 °C)

3. The resulting purified trichlorosilane is thermally reduced with hydrogen (method of Siemens firm).

$SiHCl_3 + H_2 \rightarrow Si+3HCl$

Methods of obtaining AUC from metallurgical silicon is technically complex and requires large investments and high operating costs for large commercial production. Production technology is not ecologically clean.

The problem of solar energy development

One of the main problems in the development of solar energy industry is creating new technologies for producing solar grade silicon, which would provide a drastic reduction in its cost due to the reduction of energy consumption, and making possible to obtain it in required amounts. In recent years the direction associated with the use of different methods of refining metallurgical silicon is being actively developed. The technology developed by the Institute of Geochemistry of SB RAS consists of three main parts: the carbothermic reduction of high-purity silicon from quartzite, a new technology of refining silicon melt, final purification of silicon from heavy elements and the formation of necessary columnar structure with directional solidification of multisilicon. The developed technology reduces the cost of electricity needed to produce 1 kg of multisilicon four times, and the cost of silicon becomes five times lower. Experimental samples multisilicon have already been obtained by the technology developed at the Institute. The basis of the technology is the use of high-purity natural quartz raw unique field super-quartzite Bural Sardag (Eastern Sayan) and pure carbon reductants, as well as a fundamentally new technology of silicon melt refining developed by the Institute.

The relevance of further study of silicon technology is undeniable. For example: In recent years there has been a steady increase in the output of solar modules (more than 30% annually), with a leading position (more than 85% of the market) belonging to photoelectric converters, which are based on mono-and multicrystalline silicon. In 2008 world production reached 5.6 GW of installed capacity exceeding 5 times the forecast made in 2001. In 2013, the production volume increased to 22 GW. The rapid growth of the production of photoelectric converters has led to a shortage of silicon solar grade. In 2008 about 50,000 tons of silicon was used. Thus high purity silicon in solar energy is able to reduce the deficit of electricity in the future.

Modern developments in production of photoelectric converters

The modern world has long been seeking to simplify and reduce the cost of production of photoelectric converters.

A new environmentally friendly fluoride method of producing polycrystalline semiconductor silicon from cheap natural quartz sand has recently been proposed. The method consists in the fluorination of dried natural quartz sand with elemental fluorine in a fiery reactor according to the foolwing reaction:

$SiO_2 + 2F_2 = SiF_4 + O_2 + Q.$

The impurity content in the resulting silicon tetrafluoride of is not more than 2 ppm, including - $\leq$ 0,06 ppm of phosphorus and ≤ 0,01 ppm of boron.

A gaseous mixture consisting of silicon tetrafluoride and oxygen is fed into the electrolytic cell with a liquid cathode under a layer of melted eutectic fluoride salts.Silicon tetrafluoride with fluoride salts forms complex compounds according to the reaction:

$$SiF_4 + 2LiF\ (2KF,\ BaF_2) = Li_2(K_2,\ Ba)SiF_6, \quad (500\ °C)$$

and oxygen does not react with the melted eutectic fluoride salt and together with volatile impurities is discharged into the atmosphere.

Complex luoride salts formed in the reaction are electrolytically decomposed with appearance of elemental fluorine on the inert anode and of polycrystalline silicon on the cathode. During electrolysis impurities that are more electronegative than silicon do not lose their charge. Due to this silicon with such admixtures as boron, phosphorus, titanium, vanadium, chromium and other impurities can be obtained on the cathode.

At 500°C polycrystalline silicon fully dissolves in the melt of zinc (liquid cathode).The melt of silicon in zinc is recrystallized (if necessary, many times) by thermal vacuum distillation of zinc. As a result, silicon is very well additionally cleaned from impurities.

One of the latest innovations has been by ThermalTechnology company (USA).It has developed the process of making solar grade silicon from rice husk.

ThermalTechnology combined carbothermic reduction process with the biomass pyrolysis of rice husk into solar grade silicon. Pyrolysis provides an excellent mixture of SiO_2 and C, which is suitable for the recovery process, with a structure that facilitates purification to eliminate random elements. Using a combination of pyrolysis and carbothermal reduction it is possible to produce material of sufficient purity for use in the solar power industry.

Black silicon hypersensitive to light has also been developed in the USA.

A physicist from Harvard University, Eric Mazur has created a new material called "black silicon". The investor which supports research is the U.S. company SiOnyx, which invested $ 11 million in the project.

During experiments on catalytic reactions on metal surfaces, the scientist changed the direction of research and sent a laser beam onto a silicon wafer. Elegas (sulfur hexafluoride) was used as the catalyst. The silicon obtained after treatmentwas black. The surface of the plate was covered with a variety of the subtlest particles.

In the study of the properties of the new material, it was found that black silicon has a very high sensitivity: 100-500 times higher than conventional silicon detectors. New material absorbs two times more visible light than conventional silicon and may perceive the infrared radiation which is not caught by modern silicon devices.

At present experiments aimed at studying the photovoltaic characteristics of black silicon are being conducted. SiOnyx is not going to produce their own solar panels using the new technology and will provide the technology for enterprises engaged in the solar energy industry.

Manufacturing of thin film solar cells, which comprise only about 1% of silicon in relation to the mass of the substrate, on which thin films are deposited, is also being developed. Due to the low consumption of materials thin-film silicon solar cells are cheaper to produce, but still have a lower efficiency and unrecoverable degradation of characteristics over time.

Conclusion

Photoelectric converters on silicon base have immense prospects of development because solar energy is one of new types of energy production, which is based on renewable resources. This kind of energy is inexhaustible, does not produce harmful waste. Moreover, it is environmentally friendly and can be considered as a potential energy resource, which is able to revolutionize the modern concept of energy supply and fully meet the needs of humanity.

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