ISSN NO: 2770-0003
Date of Publication: 17-02-2022

Production of micro- and nanoscale silicon granules using powder technology

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Annotation: This paper describes in detail the operations performed on the extraction of nanostructures by the powder method, the use of powder technology and the purification of silicon granules obtained from the pulverization technology using a magnetic field (magnetic method), which is one of the most convenient methods of purification. X-ray diffraction analysis of granulated silicon semiconductor material to the nanoparticle state is shown. The final product consists of granules. Preliminary research shows that silicon powders range in size from 400 nanometers to 1,000 micrometers, and that their surface is made up of a variety of rough irregularities.

Keywords: Nanostructure, silicon, metallurgy, special ball mill, granule, powder, single crystal, polycrystalline, semiconductor materials, alternating electromagnetic field, magnetization

It is known that powder technology is widely used in metallurgy for the production of various plates, surface treatment of materials and other purposes due to its simplicity, reliability and the fact that it does not require complex operations [1 ÷ 3].

The production of nanostructures using the powder method can be explained as follows. Powdering is carried out in special mills. A simplified diagram of the mill is shown in Figure 1. In terms of the structure of the mill, it consists of a cylinder (1) and steel (2) spheres rotating around its axis. Initially, the raw material is ground to a size of 2 mm (3) and ground in a mill. Ethyl alcohol is used to ensure the quality of the powdering process. This process can be compared to making flour from wheat using a mill. It is known that in the production of flour, wheat grains are first moistened to a certain extent. This, firstly, makes the wheat easier to grind and, secondly, increases the viscosity. A similar physical[8] process occurs during the powdering of crystal particles.

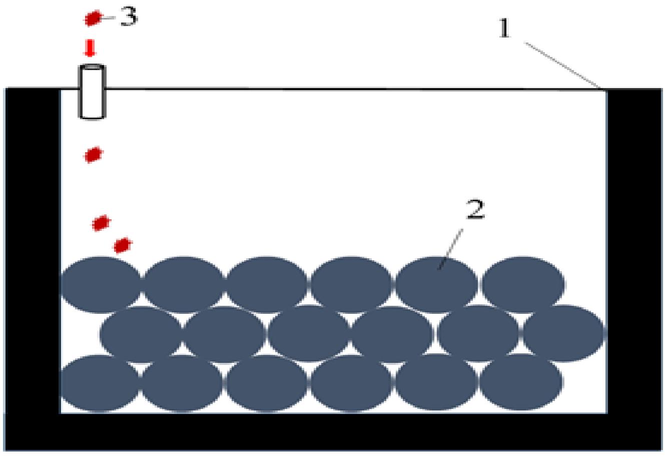

Figure 1. Simplified scheme for obtaining nanostructures using a mill. 1 - cylinder, 2 - steel balls, 3 - pulverized particle.

However, due to the fact that the preparation of powders is carried out mechanically, intrusions from the external environment can lead to the formation of various defects in the volume or surface of the material. In addition, one of the disadvantages of powder technology is the contamination of the powder from the raw material to the preparation of the powder. In order to solve these problems, initially, washing

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and vacuum drying were carried out to remove the powder. The powder was then cleaned by a special magnetic method [1 ÷ 3]. It should be noted that the grinding process was carried out with a high-hardness ceramic hammer and a smooth ball mill. Because the process takes place at room temperature[6-7], no chemical reaction occurs between the input atoms and silicon, which are invaded by the external environment. Therefore, the magnetic method allows you to completely remove silicon dust from the environment and from magnetic waste. Figure 2 shows a schematic of a semiconductor material [5] powder.

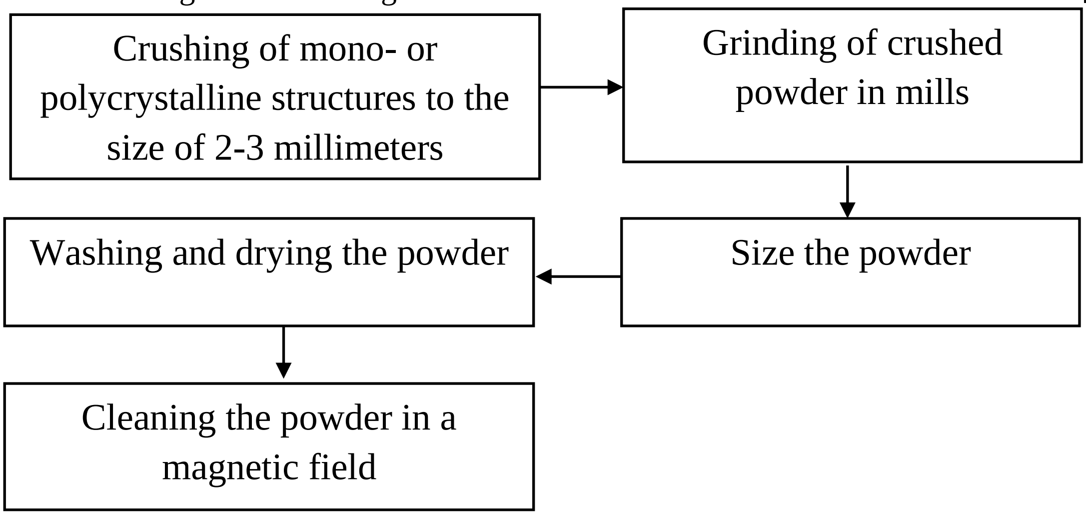

Figure 2. Semiconductor powder coating scheme.

The process of powdering semiconductor materials consists of 5 parts. Initially, mono or polycrystalline semiconductor[2-4] materials are ground to 2 and 3 millimeters, and then the crushed crystals are passed through a mill. The powder formed in the mill is divided according to its size. The separated powder is washed and dried under vacuum. It is then magnetically cleaned of external contaminants. The final product consists of granules. Preliminary research shows that silicon powders range in size from 400 nanometers to 1,000 micrometers, and that their surface is made up of a variety of rough irregularities.

Magnetic method of powder cleaning

This method is simple, the initially dried powder is passed through a magnetic field. Permanent magnetic or alternating electromagnetic fields can be used as a source of magnetic fields). This is determined by the degree of contamination of the powder. It is advisable to take into account the material of the tool used in the crushing of raw materials, the magnetic properties of the inputs penetrated by the external environment, the degree of their formation of compounds with semiconductor materials. Typically, steel hammers are used to grind crystals, and mill balls are also made of steel. During the grinding process, iron fragments from hammers and steel balls can become part of the powder. Because the process is carried out at room temperature, there is no chemical reaction between the input atoms and the powder, such as silicon powder, which is absorbed by the external environment. However, this process leads to dust contamination.

The powder cleaning method does not require additional energy and is inexpensive. First, let's look at how to remove dust in an alternating electromagnetic field (see Figure 3). A metal tube is placed vertically in the alternating electromagnetic field. The powder is passed through a tube. In this case, the magnetic powder adheres to the wall of the metal tube. After cleaning the tube, the powder is re-passed through the tube for control. Once the powder is clean, it is considered usable.

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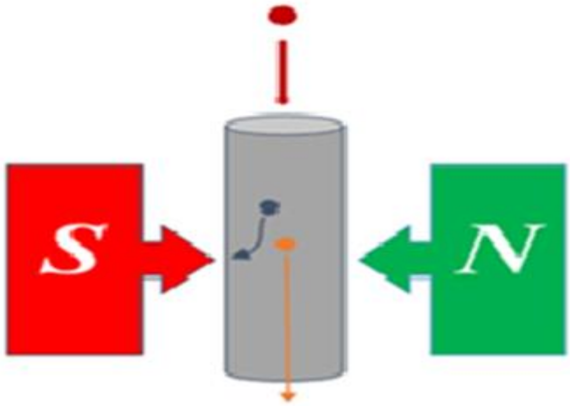

Figure 3. Alternating magnetic field cleaning scheme.

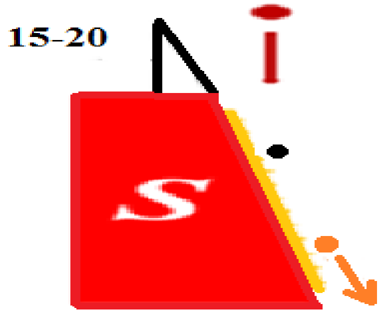

Figure 4. Permanent magnetic field cleaning scheme

Now let's look at the process of cleaning dust in a permanent magnetic field. To do this, a filter paper is placed on the magnetic surface at an angle of 80-85 degrees (Figure 4). The powder falls on the surface of the filter paper in the required amount. During the friction of the powder with the filter paper, the magnetic inclusions remain on the surface of the paper. The result is a layer of inserts on the surface of the filter paper. The process of preserving magnetic resins on the surface of filter paper can be explained as follows.

It is known from magnetostatics that the magnetization of permanent magnets indicates the presence of microcurrents in them. The process of magnetization is observed in substances introduced into the magnetic field. The process of magnetization is similar to the process of charging. This phenomenon is especially strong in metals. When dust passes through a magnetic field, metal particles are magnetized or charged by the field. As a result, they are stored on the filter paper on the magnetic surface. This will require repeated replacement of the filter paper and re-cleaning. With each change of filter paper, the number of input atoms on the surface of the paper decreases. This process is performed until the filter paper is 100% clean. Our research has shown that it is enough to change the filter papers 4 times. Let's take a look at the results of this study below.

Figure 5 shows the X-ray spectral characteristics of the inclusions on the surface of the silicon wafer obtained using powder technology. Silicon with a polycrystalline structure containing alkali metal atoms was used as the starting material.

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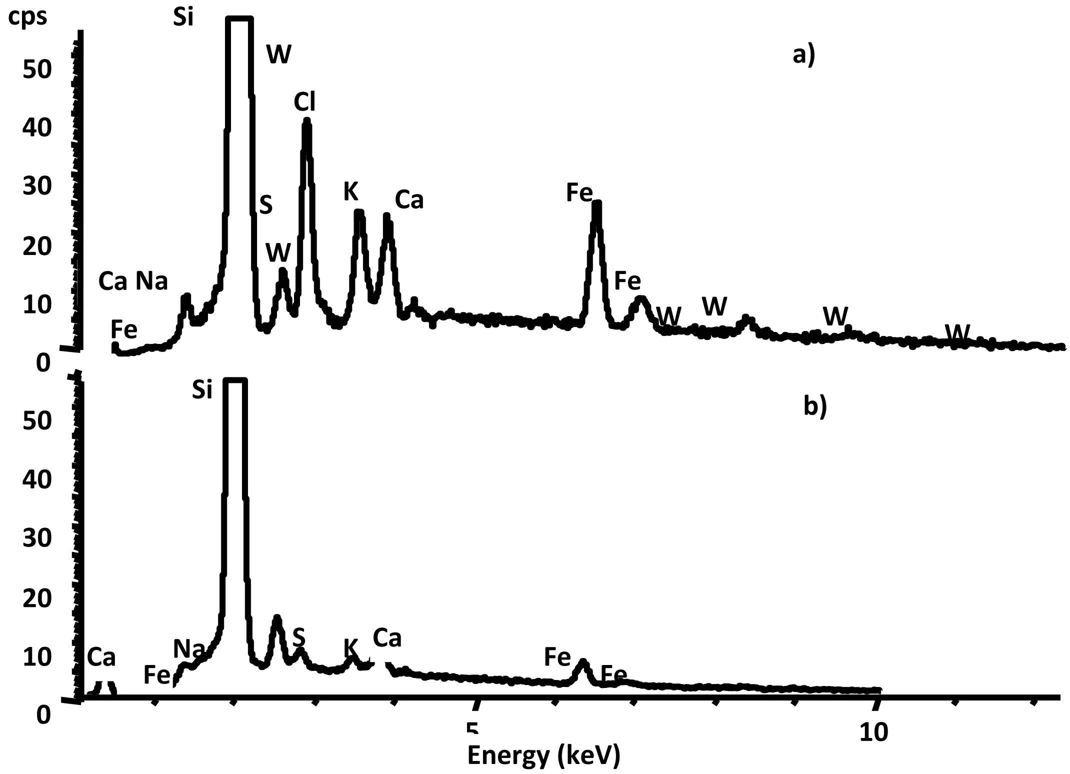

Figure 5 X-ray spectral characteristics of the inputs.

a) uncleaned b) magnetically cleaned plates.

Figure 5 shows that samples that have not been cleaned contain various metals, such as Fe, Ca, S, and other impurities. This indicates that particles from hammers or steel balls have become part of the powder during the grinding process. After the powder was passed through a magnetic field, it was found that the input signals detected above were significantly reduced. The results of the study show that the magnetic method allows to remove 90 ÷ 95% of the dust from the input atoms.

Conclusion

The particle size obtained by the powder method is in the range of 10 ÷ 1000 nm. One of the advantages of this method is that it is possible to make compounds that are difficult to obtain chemically during the synthesis process by mechanical action. For example, during the grinding process, the powder that collides with the steel balls heats up. During the heating process, there is a temperature difference across the size of the powder crystal. Depending on the temperature difference, we can divide the powder into 3 parts. On the surface with a relatively high temperature, the needle-fiber bundle (1) is the area that separates it from the powder core (3). In the process of mechanical action, the atomic structure of these spheres is radically different from each other. It is difficult to obtain such a structure chemically. As we have seen, nanoparticles with different atomic or molecular structures are formed during dusting.

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