TECHNICAL SCIENCES

FROM SILICON TO CUTTING-EDGE DEVELOPMENTS: ALTERNATIVE SEMICONDUCTOR MATERIALS

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The article discusses the issue of semiconductor materials and chemical compounds used to make the element base for electronics. The article also provides a brief description of modern materials alternative to silicon and germanium, which are being actively researched and are gaining momentum in the raw materials market for the production of electronic and radio engineering devices.

Keywords: silicon, germanium, gallium arsenide, graphene, molybdenum.

Semiconductors are used to solve various electrical engineering problems. They are used in many industries, such as the operation of machines and mechanisms, control of production processes, generation of electrical energy, amplification of high-frequency vibrations and generation of radio waves, creation of heat or cold by means of electric current and other processes. Semiconductor materials include most minerals, non-metallic elements of groups IV, V, VI of the periodic table, inorganic compounds (oxides, sulfides), some metal alloys and organic dyes [4, p. 5].

In electronics, silicon, germanium and gallium arsenide are widely used as raw materials for the manufacture of many semiconductor devices.

However, silicon, which is used to make most electronics, is already at the limit of its capabilities in terms of producing smaller electronic devices. Technologies are improving at a tremendous rate, and in some places are approaching the limits of technological dimensions, and this requires a fundamentally new direction in the development and use of semiconductor materials.

Silicon (Si) is widely used in electronics, but it conducts heat poorly, which means that devices based on it require expensive cooling systems to avoid overheating and operate stably – and this is very unprofitable.

Like silicon, germanium is used in the manufacture of semiconductor devices. As a semiconductor, germanium is used in the manufacture of transistors and other electronic devices, and it can also be used as a cathode in vacuum electronics.

Although the content of germanium in the Earth's crust is negligible, it is one of the best-studied semiconductor materials. It was germanium that historically defined the scientific and technological revolution in semiconductor electronics, although it later gave way to silicon [3, p. 3].

But germanium (Ge) also has significant disadvantages that limit its use: it is unsuitable for the manufacture of microcircuits, as it is impossible to create oxide insulation of active areas; due to the relatively narrow prohibited zone, the temperature range of germanium devices is much narrower than that of silicon devices (from -60 to +70°C) [3, p. 3].

However, germanium has retained its importance for the manufacture of a limited range of diodes and transistors, including some types of avalanche, tunnel, point high-frequency and pulse diodes, Hall sensors, detectors of ionising radiation, etc.

Currently, two applications for germanium remain unrivalled: the production of infrared optical parts and in dioxide form for textile optic communication lines.

Simple semiconductors do not always meet the requirements of modern semiconductor manufacturing and modern radio engineering. Therefore, inorganic and organic semiconductor compounds consisting of atoms of various chemical elements are widely used to create materials with specific properties.

Among these chemical compounds, gallium arsenide (GaAs) holds a special place. This compound is widely used in technology due to its good electrical properties, high chemical resistance and mechanical strength, as well as photovoltaic and luminescent properties. The high mobility of its electrons makes it possible to create GaAs-based devices capable of operating at high temperatures (up to 400°) and high frequencies.

Gallium arsenide is used to make LEDs, parametric and tunnel diodes, Hahn diodes, lasers, field-effect transistors, solar cells, and some integrated circuits.

However, modern semiconductor devices, automation and tele-mechanics devices require the use of high-quality materials and knowledge of their technological properties for proper operation. The requirements for material properties are constantly growing, which poses the challenge of fusion materials with specific properties.

In addition to the well-known and widespread semiconductor materials listed above, there are a number of promising materials, such as graphene and molybdenum disulfide.

Graphene was discovered in 2004, but it was only in 2016 that its capabilities were explored and exploited. It is one of the most promising materials for developing new technologies in many industries. Its invention in 2004 brought Andrey Heim and Konstantin Novoselov the Nobel Prize in Physics. The international Graphene Flagship project was initiated by the European Union to further commercial application this unusual structure.

Super-sensitive sensors capable of detecting a single electron have already been created on the basis of graphene. This material is used to create nano-capacitors with a large capacity. It is also used to create experimental transparent touch screens. The first attempts to use graphene in medicine for the treatment of malignancy were successful. Graphene-based field-effect transistors from IBM are promising. This material can be used to manufacture nano-capacitors that can solve most of the problems associated with multitasking, size and processing of large amounts of information. In addition, graphene could eventually completely replace other materials and become a universal semiconductor, but the lack of a band gap makes the volt-ampere characteristic symmetrical about zero and makes it difficult to obtain logical 0s and 1s. In addition, graphene, like silicon, reacts to radiation, making it impossible to use it in space projects [1, p. 2].

Graphene, thanks to its unique electronic system, reveals new fundamental effects and demonstrates phenomena previously predicted in theory. Scientists have demonstrated quantum effects such as the Klein paradox and the quantum Hall effect in their work with graphene. Graphene has record thermal conductivity and high electrical conductivity, as well as chemical and thermal stability.

Molybdenum disulfide is not inferior to graphene in terms of its potential. This is a two-dimensional material that is a bandgap semiconductor with high electrical conductivity and strength, as well as the ability to reflect light, making it useful for creating electronic devices with high image quality, such as displays. It can also be used to create more efficient solar cells. The use of this material makes it possible to implementation semiconductors as thin as one atom. Although this material is compared to graphene, it is still at the research stage [1, p. 2].

Molybdenum and molybdenum alloys are also used in parts that operate for a long time in a vacuum of up to 1800°C (in rocket nozzles and in electric vacuum devices), as a structural material in power nuclear reactors, and for the manufacture of equipment operating in aggressive environments.

Technologies are improving at a tremendous rate, and in some places are approaching the limits of technological dimensions. Reducing the size of electronic device components is becoming more and more expensive and complex, all of which requires the search for the latest technologies that will increase the speed of various technical processes.

REFERENCE:

1. Knysh B. P., Nakonechnyi V. V. Perspective semiconductor devices. URL: https://ir.lib.vntu.edu.ua/bitstream/handle/123456789/36850/123763.pdf?sequence=2&isAllowed=y

2. Odnodvorets L. V., Pazukha I. M. Materials and components of

functional electronics : a textbook. Sumy: SDU, 2020. 196 p.

3. Simple semiconductors. Examples. URL: https://studfile.net/preview/9729638/page:3/

4. Chervonyi I. F. Production of semiconductor materials : lecture notes / I. F. Chervonyi, S. G. Yegorov, R. M. Volyar. Zaporizhzhia: ZDIA, 2006. P. 5.