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Research of Graphene Instead of Silicon to Produce Supercomputers

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Abstract:

Graphene is an emerging material in the field of electronics and electrical engineering in recent years, and it is composed of only a single layer of carbon atoms, which gives it some properties that many other materials do not have. For example: high conductivity, high carrier mobility, etc. Due to its excellent performance, it is widely used in many electronic devices, among which supercomputers are a typical example. Graphene replaces silicon in supercomputers to produce transistors for use in supercomputers, and it has its own drawbacks in the process of using graphene in the process of scientists because it is not entirely advantageous. This article will discuss the advantages and disadvantages of graphene as a substitute for silicon in supercomputers. In the first part, this paper will briefly introduce how graphene is made, the sources of demand for graphene, and how graphene works instead of silicon in supercomputers, then introduce the advantages of graphene, and finally introduce the disadvantages of graphene and how to deal with it. The research in this paper will be of great value for the further research and application of graphene.

Keywords: Graphene; Silicon; Supercomputer; Transistor.

1. Introduction

As the name suggests, a supercomputer is a type of computer that performs better and is more efficient. Supercomputers typically have a power of around 40 megawatts, and this high power brings higher efficiency, but also higher energy consumption, so scientists need new materials to help further improve energy efficiency and reduce energy consumption. Through multiple experiments and comparative data, scientists have discovered materials such as black phosphorus, graphene, boronphenol, etc. Among these materials, black phosphorus has some superior physical properties, such as high mobility and tunable bandgap, which make it potentially useful in the field of semiconductors and photonic electronics. However, these key attributes are not directly applicable to supercomputers. The problem with borol is that it is too small, and the construction of supercomputers requires technical support and specific materials, and the applications of black phosphorus in these areas have not been fully developed and verified. Due to the special application fields and needs

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of supercomputers, they have strict requirements for the size and performance of hardware devices. Its small size means that it may not be able to meet the hardware resources required by supercomputers to process large-scale data and complex computing tasks. So, among these materials, graphene is best suited for supercomputers. As silicon-based electronics push the limits of performance and capacity through size, the attention of the semiconductor field has turned to graphene, a material made up of a single layer of carbon atoms arranged in a honeycomb lattice. The high mobility of its carriers (electrons and holes) may lead to its frequent application in the next generation of high-performance devices. However, due to graphene's poor on/off current ratio due to its zero bandgap, it is unlikely to completely replace silicon. Nonetheless, it can be used, for example, to improve silicon-based devices, especially high-speed electronics and optical modulators, for example by synthesizing silicon carbide [1]. The unique properties of graphene make it one of the basic materials for many energy sources, before the use of graphene electrodes, lithium was mainly used in energy production units, but since the invention of graphene, the situation with electrodes has changed. Lithium-ion batteries are now combined with graphene electrodes to improve the efficiency and energy yield of the device [2]. In the first sub-topic, this article will introduce the specific structure and application principles of graphene in supercomputers, and show the location of graphene in transistors. In the last two subtopics, this article will explain the advantages and disadvantages of graphene in specific applications and propose solutions to address some of the disadvantages.

2. How graphene and silicon work in supercomputers

Graphene is a revolutionary material known for its exceptional strength and unique properties. Graphene was first successfully produced in 2004 by Andre Geim and Konstantin Novoselov, two distinguished scientists from the prestigious University of Manchester in the United Kingdom. The two ideated researchers stumbled upon a method that is very simple but very effective at separating graphene. Their breakthrough technology enables meticulous extraction of ever-thinner flakes from graphite, a form of carbon.

The initial stage of their innovative process involves finely stripping a thin layer of graphite from a highly oriented block of pyrolytic graphite, a material with a highly ordered structure. Next, the researchers glued two sides of the extracted graphene sheets onto special tape. The next key action is to carefully tear the tape, which causes the graphene sheet to split in half. The action of removing the tape is repeated constantly, and the thickness of the graphite sheet decreases with each cycle. Finally, after several operations, the scientists succeeded in isolating a thin sheet composed of a single layer of carbon atoms, which also represents the first birth of graphene. This groundbreaking achievement not only opens new avenues for scientific research, but also lays the foundation for many technological advances, such as redox method, solvent exfoliation, chemical vapor deposition, etc(These are some of the methods of making graphene that appear later.),demonstrating the incredible potential of this single-atom-thick material.

In recent years, silicon-based transistor speeds have hit a bottleneck, mainly due to scaling techniques and short-channel effects. To put it simply, silicon-based transistors cannot be reduced to shorter lengths, and if they continue to be shortened, the performance of silicon-based transistors will be affected, and its conductivity will decrease. The opposite is graphene, which shows good value in terms of electrical conductivity. As a result, graphene appears to alleviate the shortcomings associated with silicon-based transistors, and it is for this reason that graphene is considered one of the most promising candidates to replace silicon in nanoscale and transistor applications. The main problem with graphene is that graphene is inherently gateless, whereas transistors need a bandgap with good on/off logic correlation. The thickness advantage of graphene makes it not subject to the heat dissipation limitation per unit area caused by shrinkage, so it is highly sought after by the scientific community [3].

Due to the size constraints of silicon metal-oxide-semiconductor field-effect transistors (MOSFETs) in recent years, new materials and device concepts need to be introduced. Single-layer graphene is a two-dimensional material with a crystal lattice consisting of regular hexagons with a carbon atom at each corner. The bond length between adjacent carbon atoms is 1.42 Å and the lattice constant A is 2.46 Å. Graphene is often used as a channel for transistors in supercomputers, connecting the source and drain, but it will not be a completely independent channel because graphene is a zero-bandgap material. Scientists typically make a thin layer of graphene attached to silica, and the benefit of this adhesion effect is that due to graphene's excellent mobility and ductility, graphene can scale to shorter channel lengths and achieve higher speeds without the undesirable short-channel effects that limit the performance of existing devices. As a result, the performance is improved without completely replacing the silica. However, the parasitic capacitance of such devices is too large to integrate with other components, so a true graphene transistor requires a top gate. Graphene MOS-

FETs with a top gate were first reported in 2007 [3]. The different types of graphene MOSFETs are shown: back-gate MOSFETs (Fig. 1), a top gate (Fig. 2), where the channel is partially stripped graphene, or graphene grown on a metal and transferred to a silicon wafer coated with SiO2, and the top gate (Fig. 3), where the channel is epitaxial graphene. The red channels shown here can be composed of graphene nanoribbons or large areas of graphene [4].

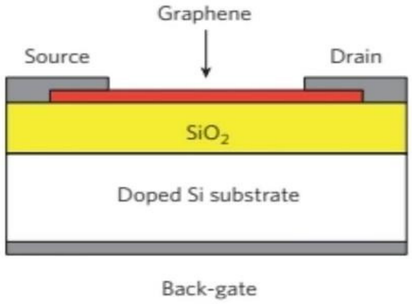

Fig. 1 Back-gate MOSFET [4].

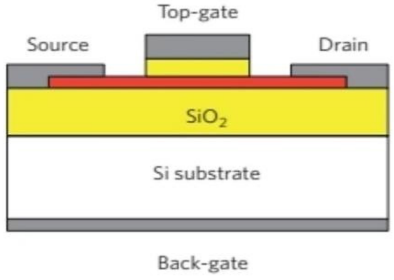

Fig. 2 Top-gate MOSFET [4].

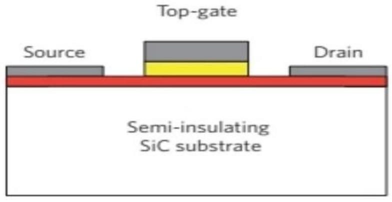

Fig. 3 Top-gate MOSFET [4].

3. The advantage of graphene instead of silicon to produce supercomputers

In today's era, graphene is a new type of material with significantly better carrier mobility than previous materials. The speed of electrons in graphene is much faster than that in ordinary conductors, and studies have shown that they can be close to one-third of the speed of light (about 1000 km/s). High-frequency circuits need precisely this characteristic of graphene, and high-speed electronic movement can greatly improve the operating speed of computers, so as to achieve the purpose of enhancing the efficiency of supercomputers. The excellent electrical conductivity of graphene, especially its extremely small layer spacing, allows for a shorter diffusion path for lithium ions, thus enhancing the electron transport performance of electronic devices. In addition, the entire outer surface of graphene is covered with lithium ions, which improves the transmission performance and further enhances the effectiveness and performance of the electronics.

Graphene not only has excellent electrical conductivity, but also has two other remarkable properties, namely flexibility and transparency. It absorbs only about 2.3% of visible light, so graphene is very transparent, reaching a state of almost complete transparency. This property makes graphene a very important material, if not essential, in the manufacture of transparent electronics. For example, in the fields of transparent touch displays, light-emitting panels, solar panels, etc., the application of graphene can significantly improve the aesthetics and user experience of products while ensuring that devices remain functional. It is because of these unique properties that graphene is seen as an ideal material for making flexible displays for supercomputers.

The softness and transparency of graphene make it perfectly adaptable to the shapes and surfaces of various electronic devices without any effect on the propagation of light. The two major properties of this material not only open up new possibilities for the development of wearable devices and flexible electronics, but also greatly enhance the advanced nature of display technology. These two advantages of graphene make it has broad application prospects in the future electronics industry, which may subvert our understanding and use of electronic devices and create a new field.

Due to its wide theoretical specific surface area and unique structural characteristics, graphene has substantial advantages when used as an electrode material. The use of graphene as a positive electrode material can significantly improve the life of lithium-ion batteries. These batteries are equipped with graphene cathodes, showing increased durability and maintaining their excellent quality after enduring more charge and discharge cycles. In the field of double-layer capacitors, the reduction of the graphene size and the increase of the interlayer spacing can effectively utilize the specific surface area of graphene. This, in turn, improves the capacitors' specific capacity and rate performance. In addition, graphene has two significant

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advantages in terms of low power consumption and high carrier saturation speed. Transistors made of graphene show higher switching speeds and lower energy consumption, making them highly efficient. In supercomputers, graphene is a key component in the transistor, acting as a conduit connecting the source and drain, thus facilitating fast and efficient data processing.

4. The disadvantage of graphene instead of silicon to produce supercomputers and the solutions to the problems

Due to the observation that graphene has excellent carrier mobility, much of the discussion about the graphene prospect has been positive. As a result, people tend to ignore the problems they are experiencing.

Graphene, a material widely regarded as having revolutionary potential, has a very broad application prospect. However, one of its significant drawbacks is its high cost. The production process of graphene is quite complex and involves a series of delicate steps that rely on advanced science and technology. At present, fabricating high-purity graphene nanoribbons is still a technically challenging task, which makes it difficult for ordinary factories to handle this production process. Even when high-quality graphene nanoribbons are successfully fabricated under laboratory conditions, the high cost can discourage factories from considering large-scale production of graphene-containing supercomputers. This high cost is mainly due to the expensive raw materials, sophisticated equipment and complex technical processes required in the graphene production process. To overcome these obstacles, researchers and engineers are working to find more economical and efficient production methods. They are trying to reduce the cost of graphene production by improving existing production technologies, or by developing entirely new synthetic pathways. In addition, some research teams are also exploring how to replace the current expensive raw materials with cheaper raw materials, in order to further reduce production costs. Although these efforts have made some progress, the cost of graphene production remains high. This is mainly due to the fact that the graphene production process requires highly elaborate operations and sophisticated equipment, which are inherently very expensive. In addition, the production of graphene also requires the use of some special chemical reagents and high-purity gases, and the cost of these materials is relatively high [5].

The scientists concluded that the ideal semiconductor needs to have the following characteristics: 1) a sufficiently wide bandgap that can be combined with high thermal conductivity and excellent carrier transport performance. 2) The production steps are not complicated, but they are compatible with SiCMOS (Silicon Complementary Metal Oxide Semiconductor). 3) The stability is high enough not to affect the carrier transmission rate near the semiconductor surface. 4) Low contact resistance. However, with the current state of the art, scientists could not find materials that fully met these requirements, and they had to seek compromises [6]. Among the many materials, graphene stands out. Although the zero-bandgap characteristic of graphene is contrary to the ideal property (1), the crystal structure of graphene can be changed by doping and creating a bandgap within it. Doping can be divided into n-type doping and p-type doping, which increase the variety of charge carriers in different ways. N-type doping produces free electrons by doping pentavalent elements, whereas p-type doping produces holes by doping trivalent elements. This paper usually combine these two doping methods to form a p-n junction, and by adjusting the charge flow in the p-n junction, this paper can effectively adjust properties such as current switching and size. The Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, using copper vapor as an auxiliary and Cu Ni alloy, reported for the first time the extremely rapid growth of 1.5-inch graphene single crystals in the world. This achievement, published in Nature Materials, further demonstrates the feasibility and potential of graphene in supercomputer applications [7].

Among the many studies, the physics laboratory at ETH Zurich in Switzerland carried out another remarkable experiment. They have successfully developed a new type of adjustable electronic transistor device whose core material is graphene. The design and construction of this device is very unique, consisting mainly of a graphene island, which is surrounded by two narrow graphene sheets, thus forming a special structure. These two narrow sheets of graphene act as a connection between the source and drain, allowing electrons to travel freely between them. To further optimize and tune the performance of this device, the researchers incorporated three transverse graphene gates into the design, which effectively control the flow of electrons. In addition to this, they also added an additional back door to the unit to allow for finer adjustments. As a two-dimensional material, the zero-band gap property of graphene has been a major obstacle limiting its application in electronic devices. However, with this unique device design, the researchers succeeded in overcoming this difficulty. This breakthrough allows the advantages of graphene to be fully exploited. With this new electronic transistor device, the application prospect of graphene has become more broad, especially in the field of high-performance electronic devices. The successful experiment of this device brings great potential and hope for the future of electronic technology [8]. Although graphene's zero-bandgap nature causes graphene MOSFETs to fail to turn off, graphene only needs one layer of atom thickness to provide enough conductivity for a field-effect transistor to operate properly. The disadvantages and advantages of graphene are mixed together to achieve a balancing effect, which makes it a suitable compromise.

5. Conclusion

In general, the application prospect of graphene in supercomputers is currently very optimistic, and it is expected to become a key research and widely used material in the scientific community, although it is still in the research and development stage, but the research progress on it has been deepening, which also shows that it has driven the development of some research areas in the scientific community and can promote the process of related industries. According to the current research progress, the high carrier mobility of graphene can improve the transmission performance of electronic devices; Graphene's large theoretical specific surface area and unique structure make it very suitable for use as an electrode material; Graphene has low power consumption and high carrier saturation rate, which improves the operating efficiency of supercomputers during use. Although the cost of graphene is high, and it will be troubled by zero band gap in the process of use. However, scientists believe that with the progress and development of science and technology, the cost of graphene will gradually decrease, and in addition, the problem of zero band gap of graphene can be solved by doping. In general, in the process of use, the advantages of graphene are innumerable, and the few disadvantages can also be solved by suitable methods. Graphene's advantages and disadvantages still outweigh its disadvantages when combined, making it an ideal alternative to silicon. Graphene's advantages are attractive, but its disadvantages also make it relatively uncompetitive in the semiconductor field. Therefore, when choosing whether to use graphene instead of silicon in the transistors of supercomputers, it is necessary to apply the advantages at the suitable aspect to avoid its fatal disadvantages.

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