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NANOELECTRONICS - A STEP INTO AN INNOVATIVE FUTURE

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Relevance of the topic

Modern development of microelectronics comes to fundamental physics limits related to the reduction of transistor sizes. Further improvement of the speed, energy efficiency and functionality of electronic devices is possible only with the shift to new operating principles based on the effects that appears on nanometer scales. Nanoelectronics is designed to solve these problems. The interest in this discipline is due not only to the prospects of creating fundamentally new types of devices, but also to the need to understand the physical foundations that underlie the modern era of microelectronics. Despite a significant number of publications, many fundamental aspects of nanoelectronics remain the subject of active research, and the formation of a unified systematic picture of this interdisciplinary field is an important scientific task.

The aim of the articl is to conduct a systematic study of nanoelectronics as a new field of science: to identify its key concepts, physical principles, basic elements and research methods. To achieve this goal, the following tasks are being solved:

- analysis of the evolution of ideas about nanoelectronics and its place in the system of physical and technical knowledge;
- exploring new technical solutions and concepts underlying the operation of nanoelectronic devices;
- assessment of the impact of nanoelectronics on modern devices.

What does the nanoelectronic mean?

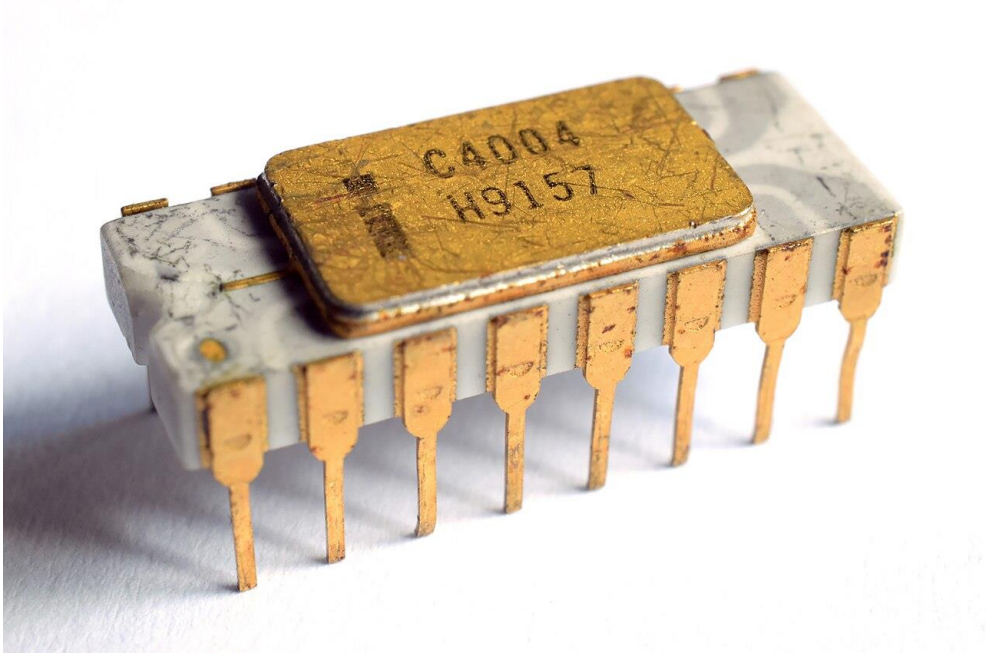
Nanoelectronics is a field of engineering and science that deals with the creation of electronic devices with nanometer-sized components. One nanometer is one billionth of a meter.. For comrehension: A human hair is about 50-100 thousand nanometers in diameter, and the diameter of the cells usually ranges from 3 to 30 micrometer s(3000-30000 nanometres). Modern technologies allows to produce transistors whose dimensions can be only 20-30 nanometer. At this size, the laws of quantum physics are already beginning to appear, from which nanoelectronics is trying to benefit. That is why nanoelectronics is based on the achievements of quantum electronics, solid state physics, semiconductor theory, and physical chemistry.

History of nanoelectronics

At its core, nanoelectronics appeared due to the development of microelectronics. By reducing the size of electronic components, scientists gradually moved to nanometer sizes.

Semiconductor electronics appeared in 1947 with the invention of transistors by Bell Labs staff — John Bardeen, William Shockley and Walter Brattain. Transistors have replaced lamps due to their compactness, reliability and lower power consumption.

In the 70s and 80s of the last century, semiconductor electronics began to operate with concepts such as heterojunctions, superlattices, quantum wires and dots, and quantum wells. It is safe to assume that even then nanoelectronics, as a division of electronics, began to take shape gradually. Completely new technologies such as molecular beam, ion plasma, ion beam sputtering, photonic annealing and many others have been introduced in the production of radio components and electronic circuits. In 1971, the first microprocessor was invented, the Intel 4004 (Picture 1), which became the basis for the development of personal computers.



Picture 1 – Intel 4004

In 1991, nanotubes based on the structural form of carbon were created. In 1998, scientists were able to obtain a transient effect based on nanotubes. At that time, the idea arose to create electronic components not from whole parts of semiconductor and other materials, but from individual atoms and molecules. These nanotubes, as it turned out later, possessed very interesting properties, for example, superconductivit.

It was from this moment that the rapid development of electronics began, including personal computers and the Internet, which continues to this day.

New technologies of nanoelectronics

Nanoelectronics has already brought many life-changing technologies. Here are some of them:

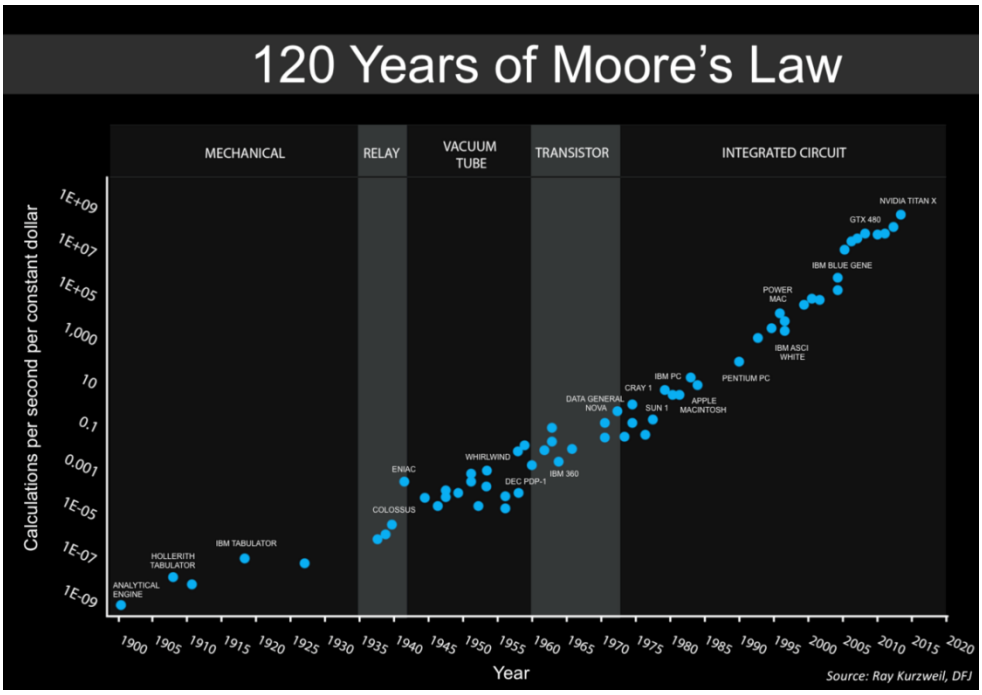
- Carbon nanotubes (CNTs) are nanoscale cylinders formed by a folded graphene sheet consisting of carbon hexagons in which carbon atoms are interconnected by a strong covalent bond. Due to the unique combination of physico-chemical properties, carbon nanotubes are considered promising for use in many fields of science. The high tensile strength and great flexibility of this material allows it to be used as an additive in various composite materials. And qualities such as high thermal and electrical conductivity make CNTs very useful for electronics. For example, CNTs can conduct sufficiently large currents without overheating due to the bonds between carbon atoms. All these qualities and their very small size make it possible to create very powerful microprocessors.
- Spintronics (spin electronics) is a field of quantum electronics that uses the spin property of an electron to encode, process, and store information. Spin can be thought of as a tiny internal magnet having two directions – up and down. By changing the orientation of the spin, you can, for example, store information. For example, in spin memory, information is stored not due to an electric charge, but due to the orientation of the spins of electrons. Spin "up" is a logical unit, spin "down" is a logical zero. Using the spin of an electron as an information carrier provides some advantages: changing the spin consumes less energy, which increases energy efficiency; spin states change faster than the charge; information is preserved even after power is turned off; reducing the size of devices. All these advantages are already being used. For example, fundamentally new quantum computers use electron spins for quantum computing, which is very fast (the clock frequency – the number of operations performed per second – of quantum processors can reach up to terahertz) and energy efficient.

How does nanoelectronics change our present

Nanoelectronics makes it possible to increase the power of computing equipment. As transistors decrease in size, their power consumption also decreases and their performance increases. But the most important thing is that the density of transistors on an integrated circuit is increasing, which directly increases the efficiency of processors and, consequently, of all devices in which they are contained.

For example, if we compare the first Intel 4004 microprocessor and one of the modern ones, we will see that the number of transistors has increased from 2,300 units in Intel 4004 to hundreds of billions in modern processors, which has increased their clock frequency from 92.6 thousand per second to several billion.

The increase in microprocessor performance is formulated in Moore's Law. In 1965, one of Intel's founders, Gordon Moore, found a pattern in the process of preparing a speech: the appearance of new chip models was observed about a year after its predecessors, while the number of transistors in them increased approximately twice each time. This resulted in a pattern that says that every two years, the performance of the chips doubles.



Picture 2 – Moore's Law

Of course, this formulation is not accurate. And currently, Moore's Law has ceased to apply due to technical limitations of the techprocess. But for decades he worked like clockwork.

Conclusion

Nanoelectronics is a young and promising field of science that can greatly change our world by introducing some laws of quantum physics into it. The results of the work allowed us to form a full view of the current state of nanoelectronics and outline the directions for its further development.

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