O. Pasichnyk, Ph.D., As. Prof.
M. Shunevych, Student
Khmelnytskyi National University

SILICON AT THE HEART OF INFORMATION AND COMMUNICATION TECHNOLOGIES

Silicon has been at the forefront of mainstream technological progress for over a century and is not about to let up. At least, scientists and engineers are not going to stop in the direction of increasing the areas of its use and efficiency. This is because it is still the one and essentially the only material used in modern CPUs and microprocessors, except Germanium. Silicon is the basis of any microelectronics related to at least some processes of information processing and control of a certain system. That is why, today, it is one of the most important components of our life.

The microprocessor built into our phone, for example, allows us to use such an incredible thing as the World Web – that's something we can't imagine our life without. Microelectronics, including microprocessors, is widely used in various devices such as phones, computers, TVs, kitchen appliances, cars, and medical equipment. These devices rely on semiconductor chips, mainly manufactured using silicon. Thus, silicon emerges as a key supporter of our modern comfort and plays a crucial role in shaping our world. It is a primary contributor to the rapid technological advancements and continuous progress in various fields that define our present existence.

Before silicon took over the world of information technology, from the 1930s to the 1950s, circuit engineering primarily used vacuum tubes and ferrite cores as the main components in electrical equipment. However, these alternatives were bulky and inefficient. In 1947 the first transistor was invented. Unlike today's counterparts, it was large enough to be pieced together by hand and mainly was made from germanium which unfortunately couldn't withstand high temperatures. So this original prototype was quickly outpaced and by 1954, Texas Instruments developed the first transistor made from silicon. Since the mid-20th century, the silicon-based transistor has played a vital role in the innovation of modern technologies, enabling the development of compact, powerful, and energy-efficient electronic components [1].

Now, we find ourselves living and experiencing the advantages of contemporary microelectronics, often unaware that we stand at the brink of the "silicon era". The rate of progress since the first silicon transistor in 1947 has been enormous, with the number of transistors on a single chip growing from a few thousand in the earliest integrated circuits to more than two billion today. Moore's law – that transistor density will double every two years – still holds true 60 years after it was proposed[2]. Nevertheless, silicon electronics faces a challenge: we've almost hit the limit on how small silicon transistors can get.

If we cannot further reduce the size of integrated circuits, silicon cannot continue producing the gains it has so far. Meeting this challenge may require rethinking how we manufacture devices, or even whether we need an alternative to silicon itself. Moving beyond silicon is essential both for developing new devices such as flexible screens and super-efficient sensors and for realizing disruptive technologies such as quantum computing and artificial intelligence. "Beyond-silicon electronics is profoundly important as it stands to revolutionize technology and our daily lives, ” – says Xinran Wang, an electrical engineer at Nanjing University [3].

In accordance with recent trends, as silicon approaches its limit in microelectronics, manufacturers have ceased doubling the number of transistors on a microprocessor chip, as it has become practically impossible. This is because below a certain size, silicon transistors begin to leak current, leading to a decline in efficiency and rendering the energy consumption of the chips 'unacceptable,' – Wang explains.

To solve this problem, Wang’s team is exploring the use of novel, non-silicon materials. These include ‘2D transition metal dichalcogenides’ (TMDs) such as molybdenum disulfide (MoS_2) and tungsten diselenide (WSe_2) [3]. Fashioning these compounds into three-atom-thick semiconductors could, in principle, make smaller and more energy efficient transistors, while avoiding the performance problems of silicon.

Recently, several research groups have reported the growth of germanene [4], a new member of the graphene family. This "alloy" of silicon and germanium is ten times more electrically conductive than silicon, and the heat release in transistors based on it is significantly lower. But it’s still under way of its development.

Scientists [2] claim that of the many materials under investigation as partners for silicon to improve its electronic performance, three have promise in the short term:

- Germanium as a replacement for silicon transistors in certain areas with a non-aggressive temperature environment. However, this shift to germanium poses challenges for manufacturers due to its historical use as the first semiconductor material.
- Metal oxides, particularly silicon dioxide, have been used in transistors for years. However, with miniaturization, the thinning of the silicon dioxide layer has compromised its insulating properties, leading to unreliable transistors. Although rare-earth hafnium dioxide (HfO_2) has been used as a replacement insulator, researchers are exploring alternatives with superior insulating properties.
- III-V compound semiconductors, such as indium arsenide and indium antimonide, are particularly intriguing. These semiconductors, especially those containing indium, boast electron mobility up to 50 times higher than silicon. When combined with germanium-rich transistors, this approach could significantly enhance processing speed.

To sum up, it is too early to talk about the total decline of silicon, particularly within the next five years. This transition is expected to evolve gradually over the next two decades. Consequently, while there is no immediate cause for concern, it is essential not to overlook the issue as it persists. The ongoing advancement in streamlining technological processes is positive, as it is preferable to anticipate reaching the "silicon threshold" sooner rather than later and initiating the search for alternatives. Thus, our current focus should be on vigilantly monitoring the situation while benefiting from the progress in modern microelectronics technologies.

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