**Gallium in Semiconductors**

When the word 'semiconductor' is mentioned, it is normal to think of silicon, as it is the key material used to make transistors, integrated circuits, and other related components. While silicon is indeed the most common semiconductor in electronic device application

, it is not alone, and other elements and compounds have also found use. In fact, the first transistor was made from germanium and throughout the 1950s it was the main material in transistors and other semiconductor devices. However, silicon was also known to be suitable for producing semiconductors and, once its processing was optimised, it rapidly replaced germanium (although it does still find use in some specialised applications).

Electronic devices do not have to be made from a single element; they can be fabricated from what are known as compound semiconductors. Instead of using a group four element such as silicon or germanium, a compound made by combining a group three and a group five element can be utilised. These so-called 'III-V' compounds have been developed for use in electronics since the 1970s, with the most popular one being gallium arsenide (GaAs) (see Figure 1).

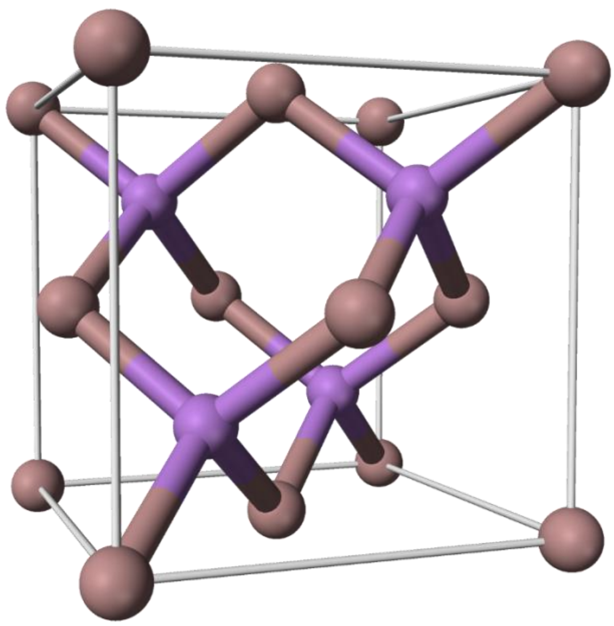

*Figure 1 The zinc blend crystal structure of gallium arsenide*

GaAs offers several advantages over silicon, making it more suitable for some applications and especially those requiring high frequency operation. GaAs components function up to around 250 GHz, meaning that they can support the signal speeds needed for the successful operation of 5G networks. They are also not affected as much by high temperatures as silicon, and they generate less noise than silicon when operating at elevated frequencies. These properties make GaAs attractive for use in mobile phones, satellite communications, microwave links and high frequency radar systems. GaAs is also used in the manufacture of Gunn diodes for the generation of microwaves. Although GaAs has been utilised in electronics for several decades, its use has often been limited by cost, as it is much more expensive than silicon. However, the industry is now reaching the point where silicon can no longer meet the required performance demands of many emerging applications and GaAs has to be used. Ultimately, this will mean that more components will be needed and, as economies of scale come into play, the costs are expected to reduce accordingly. Already, the ever-increasing demand for GaAs devices is reflected in the prediction of a 12.5% compound annual growth rate between 2021 and 2026, when the device market will be valued at $22 billion.

While GaAs is the second most popular material after silicon for fabricating semiconductors, gallium is also used in some other III-V materials and these include gallium nitride (GaN), gallium phosphide (GaP) and gallium antimonide (GaSb). These compounds have all found extensive use in LEDs (see a separate article), but they are sometimes also employed in the manufacture of a wide range of specialist and emerging semiconductors.

For example, there is currently a lot of interest in GaN. Like gallium arsenide, gallium nitride also has many advantages over silicon. This in part is due to the fact that it has a wide band gap compared to silicon, which imparts properties useful in optoelectronics. GaN components have the ability to operate at much higher voltages and frequencies reaching up into the terahertz region. Consequently, they are increasingly used in radio and radar-related applications such as air traffic control. Due to its high-power density and high voltage breakdown limits, GaN is also being used in 5G cellular base stations. GaN devices are able to operate at temperatures up to 400 ºC, making them very attractive for use in high power electronics, such as power converters (see Figure 2). Because of its high efficiency, GaN-based electronics offer significantly reduced energy consumption in applications such as power transmission and management. This is becoming an increasingly important product area, especially as the world moves towards much greater use of renewable energy sources. The currently used silicon-based converters are only around 90% efficient, with the remaining energy being lost as heat. Switching to GaN will enable smaller, lower cost, more efficient power converters to be used and for significant energy savings to be made. For example, it was reported earlier this year that Apple is planning to launch GaN versions of its USB-C power adapters, allowing them to be smaller and lighter, as well as more efficient, and generating less heat compared to the current range of chargers that use conventional silicon technology.


*Image: © Evija / Adobe Stock*

*Figure 2 Power electronic converter*

To give an indication of the increasing importance of GaN semiconductors, it is only necessary to look at the sales growth predictions. For example, sales to the defence industry and to the 4G and 5G mobile telecommunications sector alone are predicted to increase from $380 million in 2017 to $2 billion by 2024. The overall global GaN semiconductor market size was valued at $1.44 billion in 2019 and is predicted to expand at a compound annual growth rate of almost 20% between 2020 to 2027.
In summary, it can be seen that compound semiconductors offer advantages over silicon in a number of key areas. This is particularly true in the fields of mobile communications and renewables. Although there are various compound semiconductors available, gallium is a key ingredient of the most important ones, especially gallium nitride and gallium arsenide, that will increasingly be utilised in the future. In fact, the volume of gallium-containing semiconductors being manufactured is growing significantly and so is the amount of gallium needed to make them. This will ultimately then translate into large numbers of gallium-containing semiconductors reaching end of life. Consequently, they will provide another valuable source of gallium that is available for recovery, recycling and reuse in producing new electronic components.

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April 2021