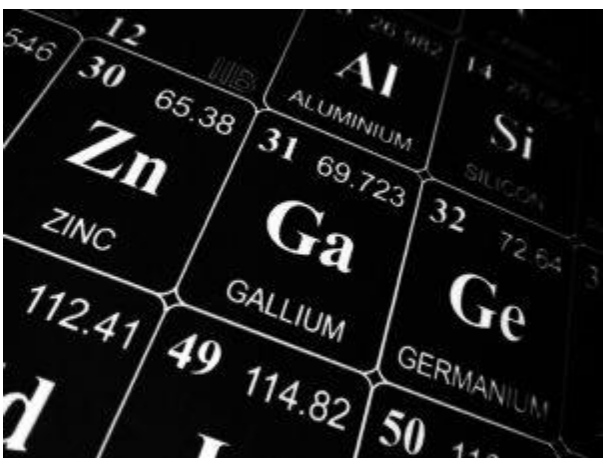
An Ideal Capacitor Solution for GaN Technology

Semiconductors are always advancing, becoming faster, more powerful, and smaller with each new technological breakthrough. These advancements are made by improving designs, processes, and materials. Recently, designers are turning to wide bandgap (WBG) semiconductor materials, such as gallium nitride, for their projects. Because these new WBG semiconductors operate at higher voltages, frequencies, and temperatures, they are enabling new application designs across many industries, including military and aerospace. But to take full advantage of these fast, high power devices in high-temperature environments, all of the surrounding support circuitry must be similarly specified to operate well under those same conditions. Capacitors are fundamental circuit elements that have a large impact on circuit frequency and are often very susceptible to high temperatures, which is why special care must be taken when selecting capacitors for use in circuits with WBG semiconductors, such as GaN devices.

What is Gallium Nitride (GaN) Technology?

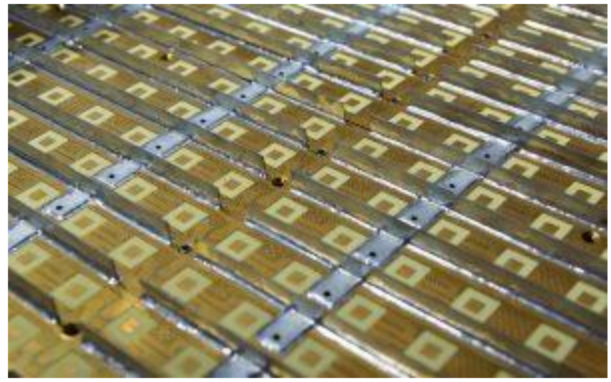


Gallium nitride, which has a very wide bandgap, is a semiconductor substrate material that has become increasingly popular in high-end, high-reliability electronics.

A WBG semiconductor such as GaN is one built with a substrate material that has characteristics falling somewhere between those of traditional semiconductors and insulators. Because of this, they can withstand higher voltages, higher frequencies, and higher temperatures than traditional semiconductors.

Materials like conductive metals have no gap between the valence band (non-conducting) and the conduction band. The bands, in this context, describe the orbital bands in which the electrons orbit the nucleus of the atoms of the material. Materials like insulating plastics have a very wide gap between their valence and conduction bands. It requires a great amount of energy to force electrons from the valence band up into the conduction band in such materials. Traditional semiconductor materials have a small gap between their bands — when biased with just a small amount of energy, such materials can be made to freely conduct electricity. And when reverse biased, they can be made into insulators.

Where Can GaN Technology Be Found?



New radar systems that rely on active electronically scanned array (AESA) technology are beginning to see widespread deployment in the defense sector. AESA offers an improvement over more traditional radar's ability to identify and track airborne, seafaring, and ground-based vehicles. It does this by creating an array of multiple emitter elements that can effectively "direct" a radar beam in any different direction without any motorized physical movement of the radio wave source. Without this need to physically reposition an antenna, AESA radar systems can last longer without physical wear out and can be easily installed on many different platforms. Beyond that, AESA radar systems can detect smaller objects at greater distances.

The AESA radar technology accomplishes this with the use of gallium nitride (GaN) wide bandgap semiconductors. The radar is made up of an array of transmit/receive modules working independently, and each module requires a high-power amplifier to increase the range and signal integrity. GaN-based semiconductor amplifiers have emerged as the leading candidate for such amplifiers.

The AESA arrays can often be constructed with 300 or more Tx/Rx modules, making space a concern. Manufacturers can leverage the high voltage, high frequency, and high-temperature capabilities of the GaN substrate to create the highest power amplifiers in the smallest possible packages. This combination of capabilities is enabling the cutting edge of radar development. But the supporting components need to rise to the challenge as well.

GaN Technology and Capacitors

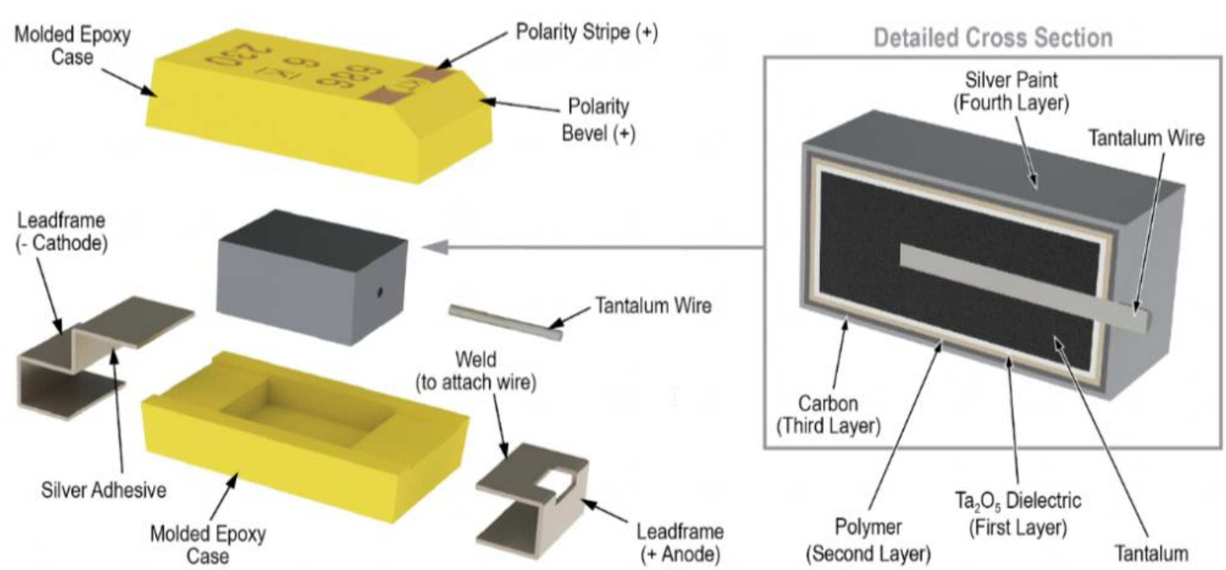
Capacitors are a critical component in any electrical circuit. They provide filtering, energy storage, and more. Most passive components, but especially capacitors, are fundamentally susceptible to changes in their characteristics at high temperatures. Capacitors can suffer catastrophic breakdowns at high voltages, and their equivalent series resistance can limit their ability to be useful at high frequencies. Because of the requirements of GaN semiconductors, traditional wet tantalum or ceramic capacitors are no longer viable options.

Capacitors to support wide bandgap GaN semiconductors must be incredibly stable over time and temperature. Ideal characteristics would include:

- Ultra-low equivalent series resistance (ESR)
- Capable of withstanding higher voltages
- Performs well at high frequencies
- Smaller form factor
- Benign failure mode
- Good current delivery
- Extended operational lifespan

KEMET’s Tantalum Polymer Solution

KEMET’s KO-CAP® series tantalum polymer capacitor is constructed with a tantalum pentoxide (Ta_2O_5) dielectric and is ideal to meet the high demands of GaN high-power amplifiers, like those required for AESA radar array technologies.



Internal construction of T540/T541 series suitable for use in AESA Designs

The T540/T541 series, for example, combines the low ESR of multilayer ceramic, the high capacitance of aluminum electrolytic, and the volumetric efficiency of tantalum into a single surface mount package. Unlike liquid electrolyte-based capacitors, KO-CAP has a very long operational life and high ripple current capabilities. These capacitors, along with T543, and the TSP stacked versions, offer deratings that perfectly match the voltage requirements for AESA applications, providing solutions for 28V, 40, and 50V power rails.

KO-CAP HRA Tantalum Polymer Series

KEMET’s KO-CAP® high reliability alternative series tantalum polymer capacitors offer customers high volumetric efficiency, high temperature ratings, and long operational life for high power and performance applications. The extremely long life expectations of this series make them ideal for military, defense, and aerospace applications. Although the example of AESA radar systems discussed here is one very clear application for these capacitors, they also work well for other high power, high frequency, long life requirement designs.