Delivered...
MACOM GaN in Wireless Basestations

MACOM™

Partners from RF to Light

The semiconductor technology landscape for wireless infrastructure is undergoing a major transformation, particularly in the power amplifier (PA) market. The multi-decade dominance that laterally diffused metal oxide semiconductor (LDMOS) transistors have sustained in the PA domain is being challenged by Gallium Nitride (GaN), and the implications for wireless basestation performance and operating costs are profound.

The clear technology advantages that GaN provides – improved energy efficiency, greater bandwidth, higher power density, smaller form factors – position it as the natural successor to LDMOS for the next generation of basestations, particularly for cellular bands above 1.8 GHz. While GaN was once prohibitively expensive compared to LDMOS, MACOM's fourth generation GaN on Silicon technology (MACOM GaN) brings their respective cost structures into close alignment.

Here we'll take a closer look at the relative merits of LDMOS, GaN on Silicon Carbide (SiC) and MACOM GaN technology, assessing their advantages and tradeoffs ranging from performance attributes to costs to supply chain ecosystems. With decades of proven experience and expertise in wireless infrastructure applications, MACOM is uniquely positioned to assess their respective suitability for commercial basestation applications.

MYTH:

GaN on Si power transistors offer negligible efficiency advantages over LDMOS, and can't match the efficiency of GaN on SiC devices.

MACOM GaN-based MAGb power transistors deliver efficiency over 70% and linear gain of 19 dB at 2.6 GHz, with the ability to achieve over 80% peak efficiency when the devices are presented with proper harmonic terminations. This power efficiency profile rivals that of best-in-class GaN on SiC devices, and represents an efficiency improvement of 10% compared to legacy LDMOS offerings.

Properly exploited, this efficiency advantage can make a profound impact on service providers' operating expenses (OPEX) through major savings in the utility bills and savings in the capital expenditures (CAPEX) through minimizing the size of the heat sink, the power supply unit (PSU) and the overall size of the remote radio head (RRH.) The utility bill savings of switching only new macro base stations deployed in a year to GaN can exceed $100M when modeled with an average energy rate of $0.1/KWh.

	LDMOS	MACOM GaN	GaN on SiC	Benefits
Power Amp Efficiency ">2GHz"	–	>10% Improvement	>10% Improvement	*Lower Operating Expense*
Higher Frequency Bands	3.6 GHz	Up to >3.8 GHz	Up to >3.8 GHz	*New Spectrum Deployments*
Wider Bandwidths	100 MHz	200 MHz	200 MHz	*Higher Capacity per Basestation*
Power Density	1-1.5 W/mm	4-6 W/mm	4-8W/mm	*Smaller Antenna, Lower CapEx*
Linearity	DPD Friendly	DPD Friendly	Charge Trapping	*Higher Order Modulation Schemes*
Supply Chain	8"	Up to 8"	4"→6"	*Capacity and Surge Capability*
Cost	Silicon	Silicon	SiC	*LDMOS Like Cost Structure*

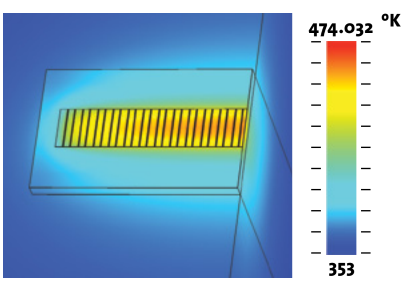
MAGb

MYTH:

GaN on SiC's thermal attributes ensure better PA reliability in the field.

MACOM's ***MAG**b* power transistor series has demonstrated MTTF over 10^6 hours at real-world basestation operating temperatures of 200° C. These devices are therefore proven to be every bit as robust and reliable in the field as competing GaN on SiC devices, and match the field longevity profiles of legacy LDMOS devices.

MACOM achieved this thermal performance parity with GaN on SiC devices leveraging advanced transistor and package design techniques. By optimizing the transistor die layout and using innovative heat sinking and die attachment methods, the 15% to 30% delta in thermal conductivity at the Si vs SiC substrate level is effectively negated at the device level.



MYTH:

GaN-based devices introduce linearity issues that are difficult to correct with digital pre-distortion.

Doherty amplifier implementations are popular for their attendant efficiency benefits, but they can magnify signal problems by introducing non-linearity. This can be corrected with digital pre-distortion (DPD), but DPD has proven difficult to implement with GaN on SiC devices. The charge trapping effects in SiC, believed to be caused by crystalline defects in its silicon structure, ultimately yield challenging and less linearizable PAs.

In comparison, MACOM GaN-based ***MAG**b* power transistors are easy to linearize and correct with DPD schemes compared to other GaN technologies. MACOM GaN doesn't exhibit the same levels of the aforementioned artifacts and is therefore a technically superior solution to both LDMOS and GaN on SiC for basestation applications.

MYTH:

GaN's power density benefits are counterbalanced by prohibitively high costs.

TO272S plastic package offers earless TO272-footprint solutions capable of up to 300 W peak power with improved thermal performance

MACOM GaN can produce 4X to 6X more power from the same transistor die size as LDMOS. And while the wafer material costs for MACOM GaN are slightly higher than LDMOS due to GaN epitaxial deposition, MACOM's wafer processing efficiency enables a 50% reduction in the number of processing steps compared to LDMOS fabrication, yielding a negligible difference in cost per wafer. Ultimately, in volume production, MACOM GaN die size will be between 1/4 and 1/6 that of LDMOS, while supporting an inherently lower cost structure.

The high power density provided by MACOM GaN naturally enables smaller device packages. Alternatively, a designer could maintain existing PA form factors while delivering higher power and/or greater integration to accommodate massive MIMO transmit/receive antenna architectures.

MACOM's ***MAG**b* power transistor series exemplifies this power density advantage. Initial entries in this product series include single-ended transistors providing up to 400W peak power, dual-transistors, and single-package Doherty configurations providing up to 700W peak power in both symmetric and asymmetric power options. The physical size of these devices is equal to that of lesser performing LDMOS devices and comparably performing GaN on SiC devices.

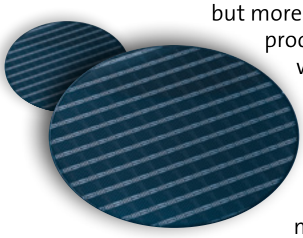
continued ⇢

MACOM GaN...Delivered

MYTH:

GaN is simply too expensive for basestation applications.

MACOM GaN is on a trajectory to yield GaN-based devices that are half the semiconductor cost per watt of comparable LDMOS products, and significantly lower cost than comparably performing but more expensive GaN on SiC wafers at volume production levels. MACOM GaN is the clear winner on cost.



4" vs. 8" Wafer

At maturity, GaN on Si stands to benefit from silicon cost structures that are 100X lower cost than today's GaN on SiC technology, owing to the 200X to 300X slower material growth of SiC boules compared to silicon, and the attendant equipment depreciation and energy consumption absorbed by its fabs. GaN on SiC will therefore remain perpetually higher cost and thus prohibitive for mainstream use in commercial basestations.

In contrast, a full year's production of MACOM GaN for the entire RF and microwave industry can be serviced in a few weeks by a single 8-inch silicon factory. MACOM's industry leadership and partner collaboration on 6-inch silicon wafer production, moving to 8-inch production in 2017, enable the capacity and requisite cost structures to break the barriers to mainstream GaN adoption in the commercial basestation market.

MYTH:

GaN can't meet the basestation industry's supply chain requirements.

The high attendant costs of producing SiC dictates that it will be serviced by a small community of high mix, low volume fabs that lack the ability to service commercial scale applications, particularly at peak demand. And whereas SiC is a relatively new material with a correspondingly short history of use in commercial scale applications, silicon has benefited from more than 60 years of industrialization and development. As such, the supply chain for GaN on Si has a host of natural efficiencies aligned in its favor. The industry's ability to support volume production of GaN on Si, maintain inventories, and accommodate surges in demand is firmly established.

Taking all of these factors into account, MACOM GaN strikes the optimal balance of performance, cost effectiveness and commercial supply chain scalability, distinguishing it as the clear technology platform of choice for the next generation of macro basestations.

For more information about MACOM's GaN solutions for wireless infrastructure, visit **www.macom.com/gan**

MACOM™
Partners from RF to Light