Department of the Navy SBIR/STTR Transition Program

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NAVSEA #2018-0515

Topic # N151-046
Low-Cost Gallium Nitride (GaN) on Diamond Semiconductors for Microwave Power Amplifiers
Modern Microsystems, Inc.

WHO

SYSCOM: NAVSEA

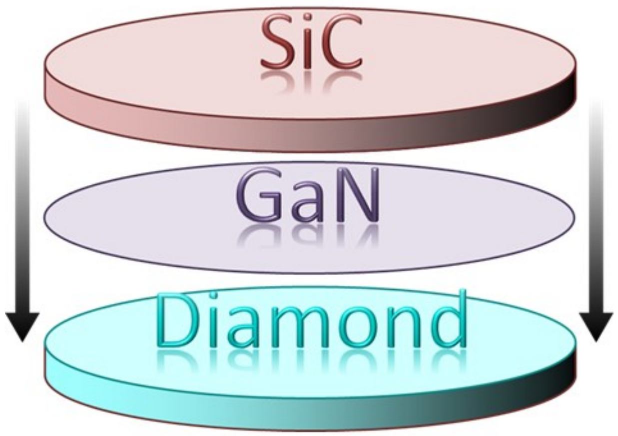
Sponsoring Program: PEO IWS 2, Above Water Sensors

Transition Target: Advanced Off-Board Electronic Warfare (AOEW), MK 53 Decoy Launching System (DLS) (NULKA)

TPOC:
(812)854-6385

Other transition opportunities: Radar and Electronic Attack

Notes: High-power gallium nitride (GaN) electronics are thermally limited. Replacing the silicon carbide (SiC) substrates on which GaN is grown with high-thermal-conductivity diamond can speed heat extraction, thereby improving device reliability, increasing power capability, reducing the size, and cutting cost.



WHAT

Operational Need and Improvement: Future Navy sensors operating in frequency bands L through X will be based on large arrays of transmit/receive modules (TRMs). TRMs deployed on a single ship may number in the thousands, representing the predominant cost of the system. Within each TRM, the radio frequency (RF) power amplifiers are typically the greatest cost component, and even modest changes to the power amplifier can have a cascading effect on total system cost.
The next evolution of GaN technology for RF power amplifiers is GaN-on-diamond substrates. Diamond offers a significant increase in thermal conductivity over silicon carbide wafers (SiC), allowing circuit elements to function at lower temperature for improved reliability, to operate at higher power for improved performance and efficiency, or to be spaced more closely on the chip thereby reducing circuit cost. The enhanced thermal characteristics of GaN-on-Diamond wafers make them especially attractive for millimeter-wave electronics, in which circuit elements must be closely spaced.

Specifications Required: The GaN-on-Diamond wafer fabrication process will be evaluated by comparing the resulting wafers with the existing GaN-on-SiC state-of-the-art, both in technical parameters (wafer flatness, defect incidence, and others) and in cost. Product quality, process consistency, and cost are paramount considerations.

Technology Developed: Modern Microsystems' GaN-on-Diamond wafer fabrication process proceeds by transfer of GaN epitaxy from a host substrate (e.g. SiC or Si) to a diamond wafer. This approach enables the independent selection of GaN and diamond materials so as to optimize price and performance trade-offs for each application. The company's advanced diamond polishing processes improve yield and reduce thermal boundary resistance by ensuring surface roughness less than 0.5 nm at the bond interface, even for large-grained polycrystalline diamond.

Warfighter Value: GaN-on-Diamond substrates can enable unprecedented performance in thermally-limited power electronics and can reduce the cost per Watt of output power by a factor of 3 or more.

WHEN

Contract Number: N00178-17-C-7004 **Ending on:** April 29, 2019

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Polishing of diamond substrates to bondable surface finish.	N/A	Roughness less than 1 nm Ra.	3	February 2016
Hall measurement of transferred GaN.	Low	Mobility and carrier concentration within 15% of initial value	4	September 2018
Thermal annealing demonstration.	Med	Survives ohmic annealing process	5	October 2018
Wafer qualification at MMIC foundry.	Med	Passes qual for use in fabrication line	6	September 2019

HOW

Projected Business Model: The transition goal is to provide a substrate fabrication process that is compatible with proprietary device layer stacks, and that can utilize the optimal GaN and diamond materials for each given application as selected by the circuit designer. Modern Microsystems can provide low-rate initial manufacturing of prototype wafers and can transfer the fabrication process to the wafer foundry of a prime or third-party manufacturer for manufacturing readiness development and production.

Company Objectives: Modern Microsystems seeks collaborators for securing manufacturing readiness development funding, manufacturers capable of housing the wafer fabrication process at production scale, and power electronics designers with applications requiring advanced thermal management.

Potential Commercial Applications: The US domestic RF semiconductor business supplies commercial as well as military markets, and advances in semiconductor and radio frequency integrated circuit (RFIC) technology, though first implemented in military systems, eventually transition to commercial product lines. Since this topic seeks to develop a process for the semiconductor material and not a specific military application, the potential for commercial application is unfettered.
Key application areas include commercial radar, avionics, and communications electronics in which thermal management is the performance-limiting bottleneck.

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