Department of the Navy SBIR/STTR Transition Program

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Topic # N18A-T004
Hot Filament CVD Technology for disruptive, high throughput SiC epitaxial growth reactors
TrueNano, Inc.

WHO

SYSCOM: NAVAIR
Sponsoring Program: PEO(U&W) PMA-262
Transition Target: NAVY Persistent Maritime Unmanned Aircraft Systems
TPOC:
(301)342-0823
Other transition opportunities: Directed Energy Weapons, Power Electronics & Electromagnetism, Adaptive & Machinery Controls and Advanced Machinery Systems
Notes: Advanced production tools for silicon carbide based power switches will significantly lower their cost and enable rapid deployment of these highly efficient devices in future Navy unmanned aircraft and directed energy weaponry.

TrueNano's SiC Deposition Tool enables cheaper SiC epi-wafers for power switches

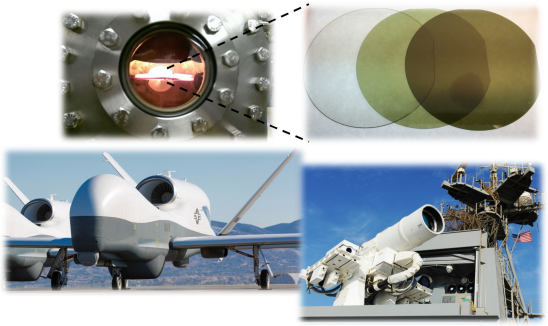

Image courtesy of TrueNano Inc. with photos taken from https://www.navy.mil/Resources/Photo-Gallery/igphoto/2002573557/ and https://www.navsea.navy.mil/Media/News/SavedNewsModule/Article/6114(leap-nswc-dahlgren-division-developed-navy-shipboard

WHAT

Operational Need and Improvement: The Navy is developing systems requiring high performance, fast switching power switches requiring semiconductors with high mobility, thermal conductivity, high breakdown voltage, and high temperature tolerance. Silicon carbide (SiC) semiconductors meet the requirements: SiC switches operate at voltages 10 times higher than Si-based power devices; operate at temperatures over 350 deg C eliminating the need for thermal management solutions; and operate at higher frequencies, enabling equipment to drastically reduce size, weight, and cost. SiC power switches eliminate up to 90% of power losses occurring in energy conversion processes, imparting significant energy benefits. The challenge is to lower the cost of SiC power switches thus low-cost manufacturing methods of SiC epi-wafers are required.

Specifications Required: A prototype deposition tool that achieves conditions of temperature, flow and pressure enabling rapid growth of 4H-SiC epitaxy, using modeling and simulation as necessary is to be constructed and tested. The process space should quantify the relationship of growth rate, polytype, uniformity, and material quality to the process parameters, like gas flow, substrate temperature, and process pressure. Improve the prototype after testing and demonstrate a path towards scaling to 6". Based on the process, develop a cost model that quantifies epi-wafer and tool costs of ownership.

Technology Developed: TrueNano is developing a SiC epitaxial deposition tool providing low cost-of-ownership, high throughput and is capable of scaling deposition up to 8". These features provide power switch manufacturers with lower cost SiC die, from which the next generation of wide-bandgap, highly efficient power switches and power controllers are fabricated. TrueNano's technology combines traditional gas phase deposition with hot-filament techniques that condition precursor gases, allowing for high growth rates and scalability--key requirements for lowering costs. The technology has been demonstrated and a prototype capable of deposition on state-of-the-art 6" SiC wafers is being developed.

Warfighter Value: The use of silicon carbide based power switches in next generation Navy platforms provides significant advantages over standard silicon based technologies. SiC devices decrease size and weight of systems while boosting efficiency and performance. These advances increase range and payload of electric, unmanned aircraft or improve the lethality and effectiveness of directed energy weapons. TrueNano seeks to accelerate their adoption by lowering the cost of the SiC materials.

WHEN

Contract Number: N68335-20-C-0027 **Ending on:** November 11, 2021

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Initial 4H SiC epitaxial and Reactor Analysis	N/A	Polytype purity, baseline process, filaments survive 100 hours operation	2	October 2018
Cost Model	N/A	Spreadsheet with Inputs and Results	2	August 2019
Reactor Design and Simulation	N/A	Design capable of achieving 1600 C, uniform gas flow profile over substrate	3	May 2020
Full Functionality Testing	N/A	20 minute deposition of SiC using	4	February 2021
Process Optimization	Med	Growth rate vs process parameters and Uniformity Profiles	5	November 2021
Scale Up	Med	Polytype uniformity over 4 inches	6	July 2022

HOW

Projected Business Model: TrueNano intends to commercialize the SiC epi deposition tool using two strategies. In the short term, TrueNano will manufacture these tools in-house, and use them to sell epi-wafers directly to small volume SiC device manufacturers. At the same time, we will pursue licensing opportunities with CVD equipment manufacturers looking to break into the SiC market with differentiated technology. These customers have manufacturing capacity to sell deposition tools to large volume, vertically integrated device manufacturers. Such a partnership will give TrueNano access to manufacturing expertise, while providing to the partner the needed SiC process and technological expertise. The horizon for this plan is estimated to be 2 years, as TrueNano advances the technology past TRL 9.

Company Objectives: TrueNano's goal is to develop a production tool that lowers the cost of semiconductor grade silicon carbide which therefore benefits the entire SiC power device industry. To date, we have demonstrated full functionality of the technology and plan to reach TRL 6 by the end of this project. At the same time TrueNano is actively seeking collaborators and follow-on funding from Navy programs that could benefit from low cost SiC power switches. Outside the DoD, TrueNano has developed relationships with interested strategic partners that are awaiting full maturity of the technology.

Potential Commercial Applications: Within the military applications include high electric demand platforms like unmanned aircraft, electronic attack systems, electric naval ships, high power RF sensors and directed energy weapons. In addition to military applications, the key private sector markets driving demand for SiC are automotive (electric vehicles), power supplies, and applications needing variable frequency drives.

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