Department of the Navy SBIR/STTR Transition Program

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ONR Approval #43-7504-20

Topic # N181-078

Novel Thermal Management Materials Technologies for High Power Naval Systems

BNNT, LLC

WHO

SYSCOM: ONR

Sponsoring Program: Naval Sea Systems Command: Electric Ships Office (ESO, PMS-320); Program Executive Office Ships (PEO Ships); Program Executive Office Aircraft Carriers (PEO Carriers); Undersea Warfare (NAVSEA 07)

Transition Target: Adv. Electronics

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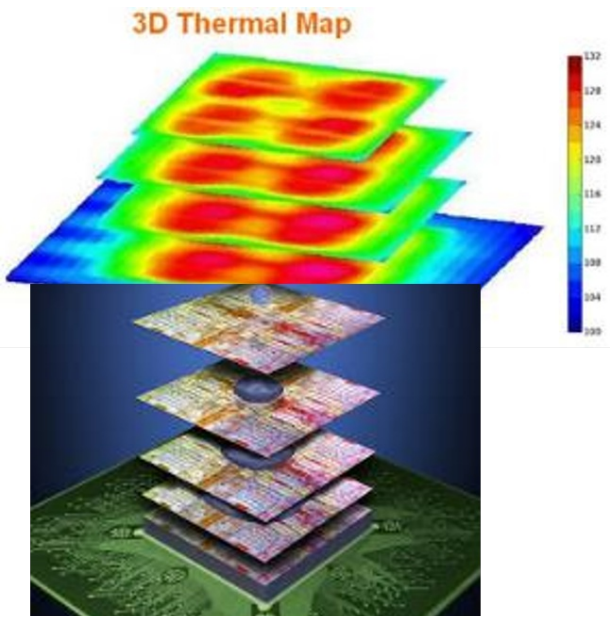
Other transition opportunities: Naval Surface Warfare Center;
Naval Air Systems Command: Naval Air Warfare Center Weapons Division, Naval Air Warfare Station China Lake (existing CRADA)

Notes: Thermal management, of performance-limiting heat, from electronics via dielectric boron nitride nanotubes (BNNT) across defense and commercial applications, with commercial joint development agreements already underway parallel to defense efforts.



WHAT

Operational Need and Improvement: Remove performance-limiting heat rapidly from ever-denser / smaller, more-powerful electronics, and their shielding, without adding size, weight, or short-circuits. Advanced dielectric (electrically-insulating) thermally-conductive materials are critical to enable high-power directed-energy (DE) and high-energy laser (HEL) diodes, but similar thermal management challenges persist across Navy Communities of Interest in RF and quantum components for advanced sensors and other advanced electronics integration packaging, power electronics, test equipment, and components for energy and power technologies to achieve higher power-density and efficiency, including at high voltages and high currents, and to exploit advances in wide-bandgap semiconductor technologies with advanced dielectric materials. Heat build-up increases signature and counters increasing need for immediately-available energy, electrical power, and especially pulsed power to support advanced sensors and weapons while maintaining power quality across users.

Specifications Required: Maximize thermal conductivity in watts-per-meter-kelvin [W/(m·K)]; minimize thermal resistance and expansion/shrinkage; quantify vibration effects and RF transparency.

Technology Developed: Using long, thin dielectric nanotubes for efficient passive thermal management, and extreme-temperature, materials.

Warfighter Value: Enable higher-capability, smaller, more-efficient, longer-lasting electronics (C4ISR) and structures, with lower fire risk and less stress on system batteries, by removing performance-limiting heat rapidly from deep within ever-denser, more-powerful electronics and platforms, even through extreme temperatures/environments and across broad frequencies.

WHEN

Contract Number: N68335-19-C-0560 **Ending on:** September 25, 2023

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Increase thermal conductivity of dielectric, viscous thermal management material for between components, without alignment	Low	>10 W/(m·K)	4	2nd QTR FY20
Increase thermal conductivity of dielectric thermal management material for within (or coating) components, without alignment	Low	>2 W/(m·K)	4	2nd QTR FY20
Demonstrate improved adhesive/sheet/pad solid thermal management material for between components, without alignment	Med	>10 W/(m·K)	4	4th QTR FY21
Aligned-fiber viability demonstrated	Med	BNNT yarns > 5 meters	4	3rd QTR FY20
Aligned-fibers more thermally-conductive than copper, but dielectric and 1/7th the weight	High	>400 W/(m·K)	4	4th QTR FY23
Aligned-fibers stronger than Kevlar	High	Tensile >4 GPa	4	4th QTR FY24

HOW

Projected Business Model: Already producing in a new pilot plant, we will expand production of revolutionary raw materials, and of select core applications, starting with low-volume high-impact uses; for more complex applications our R&D center will continue as the world-leading partner collaborating to enable implementation of dielectric, highly thermally-conductive, super-strong/lightweight nanotube fibers.

Company Objectives: As NASA Invention of the Year spin-out, with original inventors from NASA and U.S. National Labs, having formed the world's first commercial BNNT facility, and then the first and still only pilot plant, we are already automating to reduce cost, and will grow to be an advanced manufacturing engine of American competitiveness in nanomaterials.

Potential Commercial Applications: Thermal management is such an urgent shortfall for the highest-capability small/lightweight electronics systems, and their adjacent, temperature-sensitive batteries, that many such systems from first startup must be throttled intentionally to operate slower due to heat limitations. This is especially urgent for 5G telecommunications base stations and equipment using direct bonded copper in power-modules, where BNNT can not only better remove heat, but also allow thinner components by crack-bridging and reducing CTE (coefficient of thermal expansion) mismatch that causes cracking. Superior thermal management for extreme miniaturization in micro- and nano-electronics, and transparency to wireless signals (unlike carbon/graphene), will improve performance, reliability, and robustness in extreme temperatures and other harsh environments, such as thermal protection apertures for sensors on hypersonic aircraft.

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