Development of an Advanced Diamond TEC Cathode, Phase I Project

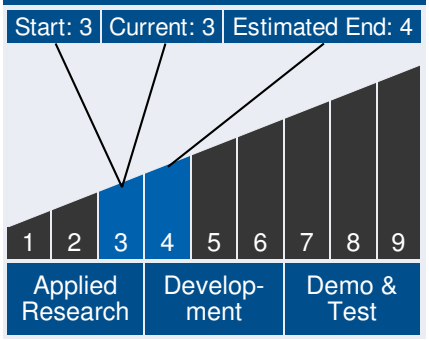
SBIR/STTR Programs | Space Technology Mission Directorate (STMD)

ABSTRACT

NASA recognizes the importance of conservation, smart utilization and reuse of resources for their deep space missions to address the need for regeneration of air, water and waste with highly reliable systems to reduce mission payload. Additionally, energy for life support and other systems needs to be obtained from renewable energy sources or waste streams. In order to address NASA's requirements of harnessing renewable energy and utilizing waste heat, IOP Technologies and Vanderbilt University propose to design and develop advanced TEC cathodes based on diamond films synthesized on flexible metallic substrates. These cathodes can not only leverage solar energy on Mars by using solar concentrators, but also use wasted thermal energy from other power sources to augment power generation. This technology can provide an efficient way of converting thermal energy into electrical energy. Studies have shown that TEC can approach total energy conversion efficiencies within 90% of the Carnot limit. As part of the proposed efforts in this STTR program, metal foil substrates such Molybdenum will be used to grow diamond thin-films in microwave plasma enhanced CVD (MPECVD) system. Diamond properties such as microstructure, electrical conductivity, quality, grain size and size distribution can be varied by adjusting the MPECVD growth parameters. The selection of diamond as the rugged and efficient emitter material is based on the excellent material properties such as negative electron affinity, low work function (less than 2eV), wide band gap (5.45eV), highest thermal conductivity (~5x that of Cu), highest Young?s modulus (~5x that of 306 stainless steel), inherently radiation hardened, highest breakdown voltage (~10 exp7 V per cm). Preliminary results from IOP research show a maximum output power of ~1mW per sq. cm at less than 100 torr pressure of hydrogen was achieved using a Diamond/Mo TEC Cathode and can be increased to 100mW per sq. cm.

Table of Contents

Technology Maturity



Management Team

Program Executives:

- Joseph Grant
- Laguduva Kubendran

Program Manager:

- Carlos Torrez

Continued on following page.

Development of an Advanced Diamond TEC Cathode, Phase I Project

ANTICIPATED BENEFITS

To NASA funded missions:

Potential NASA Commercial Applications: The advanced Diamond TEC cathodes being developed as part of the proposed program can support NASA's goal to harness renewable energy and waste heat for deep space missions, such as that to the Mars. Such a technology can leverage solar energy using solar concentrators and waste heat produced from other systems, and thus creating a more self-sustaining power generation option at remote locations as well as on transportation vehicles. These diamond TEC cathodes are ideally suited for integration with Solid Oxide Fuel Cells (SOFCs) as a power generator. SOFCs consist entirely of solid-state materials, allowing for quiet, vibration-free power production for extended periods of time with little to no maintenance. Unlike low-temperature fuel cells that can be fueled only by pure hydrogen, SOFCs can reform numerous hydrocarbon fuels such as natural gas (methane) that is available in abundance on Mars, and due to their high operating temperatures, making it an attractive prospect for NASA. SOFC power generation process is extremely efficient, achieving more than 50% efficiency when converting natural gas to electricity.

To the commercial space industry:

Potential Non-NASA Commercial Applications: Through the combination of our highly promising Thermionic Energy Conversion (TEC) research with existing Solid Oxide Fuel Cell (SOFC) technology, which has the potential to reliably supply DC power at 1/20th the cost of purchasing from the existing AC electrical grid. It has the flexibility to be fueled by numerous gaseous species (including widely available natural gas), and will produce lower greenhouse gas emissions per kWh than existing large-scale power generation technologies. Such a system will serve the needs of the United States military which often establishes temporary bases in regions lacking reliable power supply. The TEC-SOFC system can provide a reliable,

Management Team *(cont.)*

Principal Investigator:

- Weng Kang

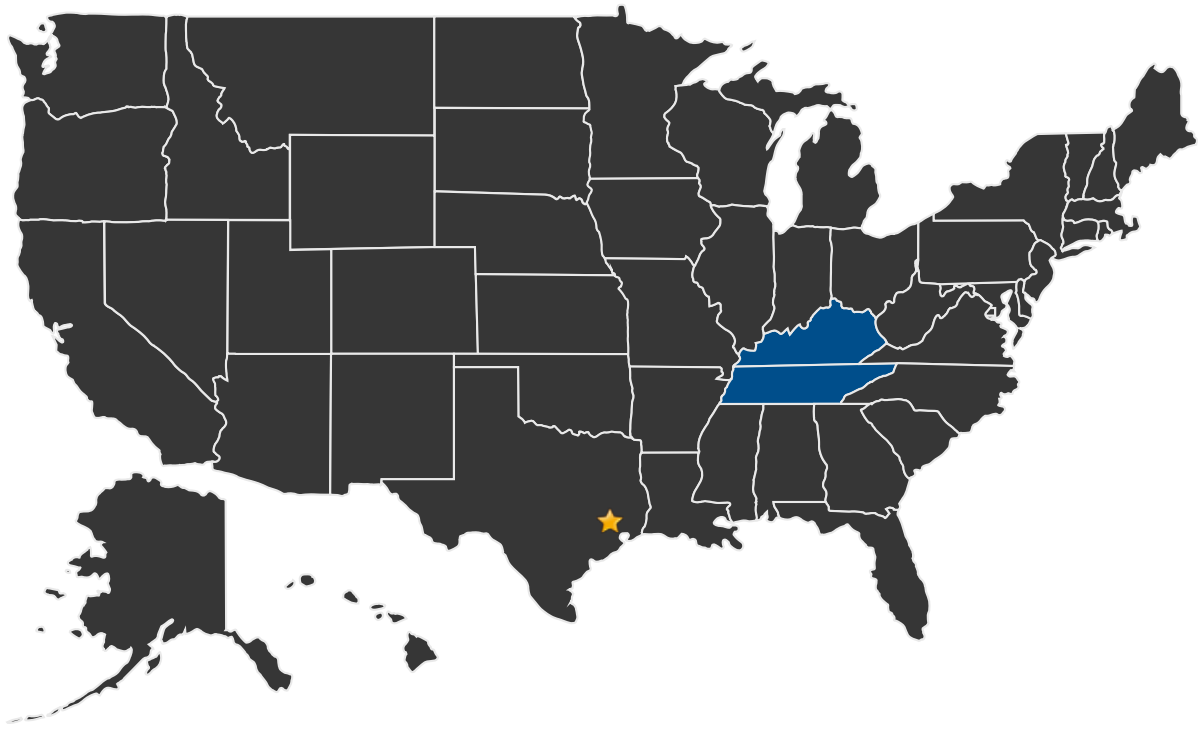
Technology Areas

Primary Technology Area:

Space Power and Energy Storage (TA 3)
└ Power Generation (TA 3.1)
  └ Energy Harvesting (TA 3.1.1)

highly portable power generator allowing for easy delivery and deployment that can utilize a wide variety of fuel sources, including JP-8, the standard U.S. Military fuel at high operational efficiency to lessen fuel resupply needs. Another possible group of customers include our electrical utility companies, such as TVA, by offering a viable alternative to the current organization of the nation's centralized, highly interdependent electrical grid. By using TEC-SOFC power generators and integrating them into several smaller, distributed, DC micro-grids would create a power system that would be virtually invulnerable to a disaster. Additionally, shifting to DC power is highly feasible and would lead to higher efficiencies due the lack of AC-DC conversions.

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Johnson Space Center

Other Organizations Performing Work:

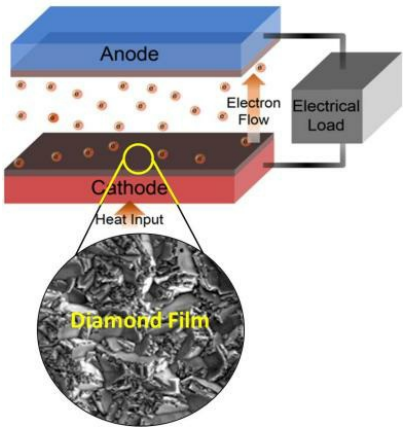
- IOP Technologies LLC (Louisville, KY)
- Vanderbilt University (Nashville, TN)

PROJECT LIBRARY

Presentations

- Briefing Chart
  - (http://techport.nasa.gov:80/file/23453)

IMAGE GALLERY



Development of an Advanced Diamond TEC Cathode, Phase I

DETAILS FOR TECHNOLOGY 1

Technology Title

Development of an Advanced Diamond TEC Cathode, Phase I

Potential Applications

The advanced Diamond TEC cathodes being developed as part of the proposed program can support NASA's goal to harness renewable energy and waste heat for deep space missions, such as that to the Mars. Such a technology can leverage solar energy using solar concentrators and waste heat produced from other systems, and thus creating a more self-sustaining power generation option at remote locations as well as on transportation vehicles. These diamond TEC cathodes are ideally suited for integration with Solid Oxide Fuel Cells (SOFCs) as a power generator. SOFCs consist entirely of solid-state materials, allowing for quiet, vibration-free power production for extended periods of time with little to no maintenance. Unlike low-temperature fuel cells that can be fueled only by pure hydrogen, SOFCs can reform numerous hydrocarbon fuels such as natural gas (methane) that is available in abundance on Mars, and due to their high

operating temperatures, making it an attractive prospect for NASA. SOFC power generation process is extremely efficient, achieving more than 50% efficiency when converting natural gas to electricity.