



NASA SBIR 2011 Phase I Solicitation

S3.05 Power Electronics and Management, and Energy Storage

Lead Center: GRC

Participating Center(s): ARC, JPL, JSC

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan/Enceladus Flagship, Lunar Quest and Space Weather missions. Under this subtopic, proposals are solicited to develop energy storage and power electronics to enable or enhance the capabilities of future science missions. The unique requirements for the power systems for these missions can vary greatly, with advancements in components needed above the current State of the Art (SOA) for high energy density, high power density, long life, high reliability, low mass/volume, radiation tolerance, and wide temperature operation. Other subtopics that could potentially benefit from these technology developments include S5.05 - Extreme Environments Technology, and S5.01 - Planetary Entry, Descent and Landing Technology. Battery development could also be beneficial to X6.02 - Advanced Space-rated Batteries, which is investigating some similar technologies in the secondary battery area but with very different operational requirements. Power Management and Distribution could be beneficial to X8.05 - Advanced Power Conversion, Management and Distribution (PMAD) for High Power Space Exploration Applications, which is investigating some similar technologies but at a much higher power level. This subtopic is also directly tied to S3.04 - Propulsion Systems for the development of advanced Power Processing Units and associated components.

Power Electronics and Management

The 2009 Heliophysics roadmap (http://sec.gsfc.nasa.gov/2009_Roadmap.pdf), the 2010 SMD Science Plan (<http://science.nasa.gov/about-us/science-strategy/>), the 2010 Planetary Decadal Survey White Papers & Roadmap Inputs (http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412), the 2011 PSD Relevant Technologies document, the 2006 Solar System Exploration (SSE) Roadmap (<http://nasascience.nasa.gov/about-us/science-strategy/>), and the 2003 SSE Decadal Survey describe the need for lighter weight, lower power electronics along with radiation hardened, extreme environment electronics for planetary exploration. Radioisotope power systems (RPS) and Power Processing Units (PPUs) for Electric Propulsion (EP) are two programs of interest that would directly benefit from advancements in this technology area. Advances in electrical power technologies are required for the electrical components and systems for these future platforms to address program size, mass, efficiency, capacity, durability, and reliability requirements. In addition, the Outer Planet Assessment Group has called out high power density/high efficiency power electronics as needs for the Titan/Enceladus Flagship and planetary exploration missions. These types of missions, including Mars Sample Return using Hall thrusters and PPUs, require advancements in radiation hardened power electronics and systems beyond the state-of-the-art. Of importance are expected improvements in energy density, speed, efficiency, or wide-temperature operation (-125°C to over 450°C) with a number of thermal cycles. Advancements are sought for power electronic devices, components and packaging for programs with power ranges of a few watts for minimum missions to up to 20 kilowatts for large missions. In addition to electrical component development,

RPS has a need for intelligent, fault-tolerant Power Management And Distribution (PMAD) technologies to efficiently manage the system power for these deep space missions.

SMD's In-space Propulsion Technology and Radioisotope Power Systems programs are direct customers of this subtopic, and the solicitation is coordinated with the 2 programs each year.

Overall technologies of interest include:

- High voltage, radiation hardened, high temperature components, such as capacitors and semiconductors, for EP PPU applications.
- High power density/high efficiency power electronics.
- High temperature devices and components/power converters (up to 450°C).
- Intelligent, fault-tolerant electrical components and PMAD systems.
- Advanced electronic packaging for thermal control and electromagnetic shielding.

In addition, development is needed in the area of advanced High Voltage Transformer-Rectifier Technology Development for Advanced Cloud and Precipitation Radars, Interferometers, and other Advanced SAR applications where an integrated Transformer-Rectifier Assembly is needed to provide increased stability in the output voltages provided to the Cathode and Collector of a Vacuum Tube (EIK). This would result in increases in the RF phase stability of the output RF Pulse or current approaches. The Transformer-Rectifier Assembly should address using innovative, single-integrated body regulator designs that regulate collector vs. cathode potential, and demonstrate increasing voltage stability over other approaches. The entire Transformer-Rectifier Assembly (Cathode-Collector-Body) should be optimized to achieve maximum energy efficiency and minimum size/mass of the system taking into account necessary high voltage insulation and potting for operation in a space environment (vacuum). Of interest are assemblies that demonstrate:

- Cathode voltages in excess of -12 kV, and Collector voltage in the -3 KV ranges with Beam currents in excess of 340 mA.
- Assemblies for which the primary winding of the transformer is driven through 60VDC (full load) switched at a nominal frequency of 40.5±1.5kHz, or higher.
- Duty cycles up to 16%.

Energy Storage

Future science missions will require advanced primary and secondary battery systems capable of operating at temperature extremes from -100°C for Titan missions to 400° to 500°C for Venus missions, and a span of -230°C to +120°C for Lunar Quest. The Outer Planet Assessment Group and the 2011 PSD Relevant Technologies Document have specifically called out high energy density storage systems as a need for the Titan/Enceladus Flagship and planetary exploration missions. In addition, high energy-density rechargeable electrochemical battery

systems that offer greater than 50,000 charge/discharge cycles (10 year operating life) for low-Earth-orbiting spacecraft, 20-year life for geosynchronous (GEO) spacecraft, are desired. Advancements to battery energy storage capabilities that address one or more of the above requirements for the stated missions combined with very high specific energy and energy density (>200 Wh/kg for secondary battery systems), along with radiation tolerance are of interest.

In addition to batteries, other advanced energy storage/load leveling technologies designed to the above mission requirements, such as flywheels, supercapacitors or magnetic energy storage, are of interest. These technologies have the potential to minimize the size and mass of future power systems.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II, and when possible, deliver a demonstration unit for NASA testing at the completion of the Phase II contract. Phase II emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into science-worthy systems.

Disclaimer: Technology Available (TAV) subtopics may include an offer to license NASA Intellectual Property (NASA IP) on a non-exclusive, royalty-free basis, for research use under the SBIR award. When included in a TAV subtopic as an available technology, use of the available NASA IP is strictly voluntary. Whether or not a firm uses available NASA IP within their proposal effort will not in any way be a factor in the selection for award.

Patent [6.461.944](#), Methods for growth of relatively large step-free SiC crystal surfaces Neudeck, et al. October 8, 2002

Summary: A method for growing arrays of large-area device-size films of step-free (i.e., atomically flat) SiC surfaces for semiconductor electronic device applications is disclosed. This method utilizes a lateral growth process that better overcomes the effect of extended defects in the seed crystal substrate that limited the obtainable step-free area achievable by prior art processes. The step-free SiC surface is particularly suited for the heteroepitaxial growth of 3C (cubic) SiC, AlN, and GaN films used for the fabrication of both surface-sensitive devices (i.e., surface channel field effect transistors such as HEMT's and MOSFET's) as well as high-electric field devices (pn diodes and other solid-state power switching devices) that are sensitive to extended crystal defects.