Phase I Project Summary

Firm: Creare Incorporated
Contract Number: NNX09CF58P
Project Title: Advanced Radiative Emitters for Radioisotope Thermophotovoltaic Power Systems

Identification and Significance of Innovation:

Radioisotope Power Systems (RPS) are critical for future flagship exploration missions in space and on planetary surfaces. Small improvements in the RPS performance, weight, size, and/or reliability can have a dramatic effect on the scientific capability of the vehicle and the overall mission costs. Radioisotope Thermophotovoltaic (RTPV) energy converters are a particular type of RPS that directly converts the heat produced by a General Purpose Heat Source (GPHS) to electrical power using a specialized Photovoltaic (PV) cell. A key element in an RTPV system is the radiative emitter that converts GPHS thermal energy to radiative energy that illuminates the PV cell. In this project, Creare and Massachusetts Institute of Technology (MIT) proposed to develop an advanced 2-D photonic crystal radiative emitter that is optimized for RTPV systems. The resulting emitter is designed to provide high emittance in the bandgap of the PV cell with low emittance elsewhere that, when coupled with advanced PV cell filter technology, will provide high system efficiency.

Technical Objectives and Work Plan:

The objective of this project was to provide a reliable, efficient, high-mass, specific power, radioisotope power system for future spacecraft and planetary missions. We worked toward this objective by developing advanced radiative emitters, which are a key component in radioisotope thermophotovoltaic (RTPV) electric power generators. The specific technical questions addressed in Phase I were:

What is the optimal 2-D photonic crystal emitter design for an RTPV system and can we fabricate it? To address this question, we designed two different 2-D photonic crystal emitters optimized for use with 0.6 eV bandgap InGaAs PV cellsm, and fabricated emitter samples using MIT's nano-fabrication facilities.

Can a 2-D photonic crystal emitter actually provide the desired emittance spectrum, and will it be robust enough for a practical system? To address this question, we conducted detailed characterization tests to measure the emittance properties of the emitter test samples.

What advantages might the tailored emission spectrum of a 2-D photonic crystal emitter provide to overall system performance? To address this question, we conducted system level modeling to compare the 2-D photonic crystal emitter with other potential emitter technologies currently being evaluated by Creare.

Technical Accomplishments:

In Phase I, we designed two candidate Photonic Crystal emitters, fabricated test samples, and characterized these samples for high-temperature emittance and durability, demonstrating that 2-D photonic crystal technology presents a feasible solution to improving the system efficiency, reducing the specific mass, and increasing the energy density of proposed systems for radioisotope Thermophotovoltaic power systems for space applications.

NASA Application(s):

NASA has a critical, long-term need for deep space power systems based on the decay of radioisotopes and the resulting thermal energy produced. These systems are critical for flagship missions to explore the outer solar system for both spacecraft and rovers. The current radioisotope converters based on thermoelectric technology are inefficient and have low mass specific power. Radioisotope Thermophotovoltaic (RTPV) energy converters have the potential to be an attractive alternative to competing radioisotope energy converter technology. RTPV has the potential to provide comparable or higher mass specific power, at similar (probably lower) conversion efficiency.

Non-NASA Commercial Application(s):

RTPV and the associated technology proposed on this project have a number of potential non-NASA government uses. Radioisotope power sources based on thermoelectrics have been used for terrestrial military applications for many years. For example, they are used to provide power for deep sea monitoring instruments deployed by the Navy. They have also been used in remote locations for monitoring stations. RTPV could be a credible alternative in all these applications. Small radioisotope batteries based on TPV have been proposed and are being developed for a number of military sensing applications. The technology being developed on this project has the potential to benefit these ongoing efforts.

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