National Aeronautics and Space Administration

Mission enabling RTPV power system demonstration using a single GPHS module

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Project Objective

This research project covers the design, optimization and demonstration of a radioisotope ThermoPhotoVoltaic **(RTPV)** power system utilizing a single general-purpose heat source **(GPHS)** module. The research objective was to demonstrate that a conceptual RTPV system has the potential to exceed the 5.5% efficiency of the multi-mission radioisotope thermoelectric generator **(MMRTG)**. The target conversion efficiency was therefore set to be 9%. The research objective was approached through extensive numerical modelling and proof-of-concept testing in three technology areas: a novel high-temperature multi-layer insulation **(MLI)**, a Nano-photonic tantalum crystal (from MIT) acting as a selective emitter and low bandgap photovoltaic cells.

FY16/17 Results:

- Single-junction InGaAs TPV cells strained on InP substrates were received from Masimo Semiconductor. These devices are designed to have a band gap of 0.6 eV and a cutoff wavelength of 2µm.
- The performance characteristics of the TPV cells with a 250 nm silicon nitride **(SiNx)** anti-reflection coating were modelled using Atlas (Figure 1).
- The performance characteristics of the TPV cells were matched to the spectral irradiance of the MIT-produced photonic crystal selective emitter (Figure 2)
- It was demonstrated numerically that this configuration is capable of producing a theoretical conversion efficiency of 27.9% compared to 11.4% for a black body emitter at 1350 K.
- Concurrently, investigation into a novel multi-layer insulator composed of 20 layers of Molybdenum foil paired with a Zetex fiberglass fabric was pursued.
- Testing of the design was performed in TVAC chamber, however, without MIT selective emitter. Nevertheless a conversion efficiency of 8% was demonstrated (Figure 3).

Benefits to NASA and JPL:

- Increased conversion efficiency is mission enabling.
- 8% conversion efficiency represents a 45% improvement over the MMRTG
- This work therefore demonstrates a 45% increase in electrical power per unit mass of PuO_2.
- This additional power can be used to provide power to more instruments.
- It is anticipated that the addition of the selective emitter will further improve the results.
- Further experimentation, not part of this study, indicates that it is possible to double the MMRTG conversion efficiency.
- Full system design enables modularization of the MMRTG modules: ideal for powering small spacecraft applications and airless-body landers.

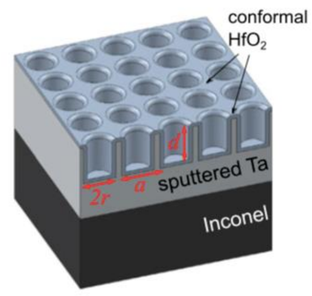

Figure 5: Nano-photonic crystal

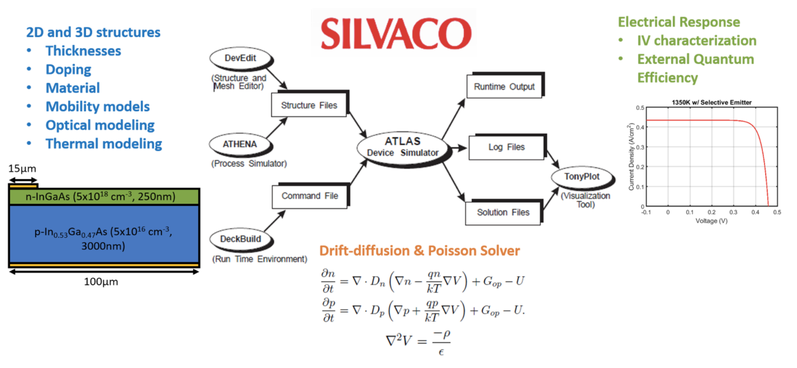

Figure 1: *Atlas (by Silvaco) simulation flow. The user enters information about device type and structure in a layer-by-layer fashion. Atlas solves the drift-diffusion and Poisson's equations and the outputs are the electrical responses (IV, EQE, band structure) of the TPV device.*

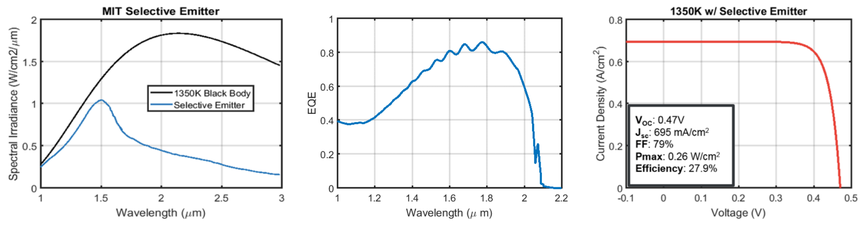

Figure 2: *Performance metrics for the Masimo InGaAs device. Left: 1350K blackbody spectrum (black) vs. the spectrum emitted by the 2D photonic crystal selective emitter (blue). Middle: EQE response with SiNx anti-reflection coating. Right: IV characteristics when the TPV device is employed with a selective emitter. Device has high efficiency but low power out.*

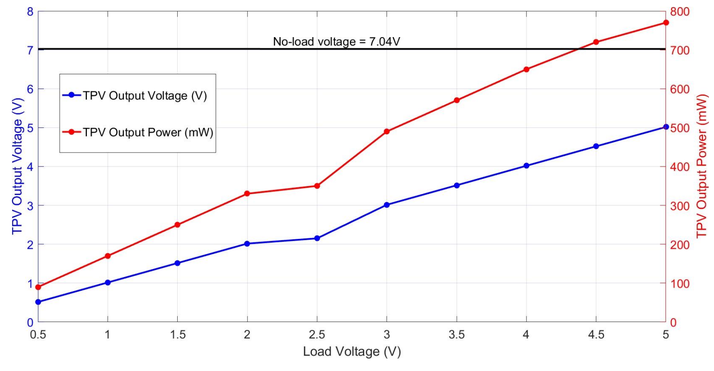

Figure 3: *Experimental results for design without MIT selective emitter. Peak TPV cell output was approximately 0.8W. Using 20 TPV cells would therefore provide 16W of output power. Thermal input power in this test was 200W and this design is therefore capable of operating at a conversion efficiency of 16/200 = 8%. This conversion efficiency should be compared to the 5.5% of the MMRTG.*

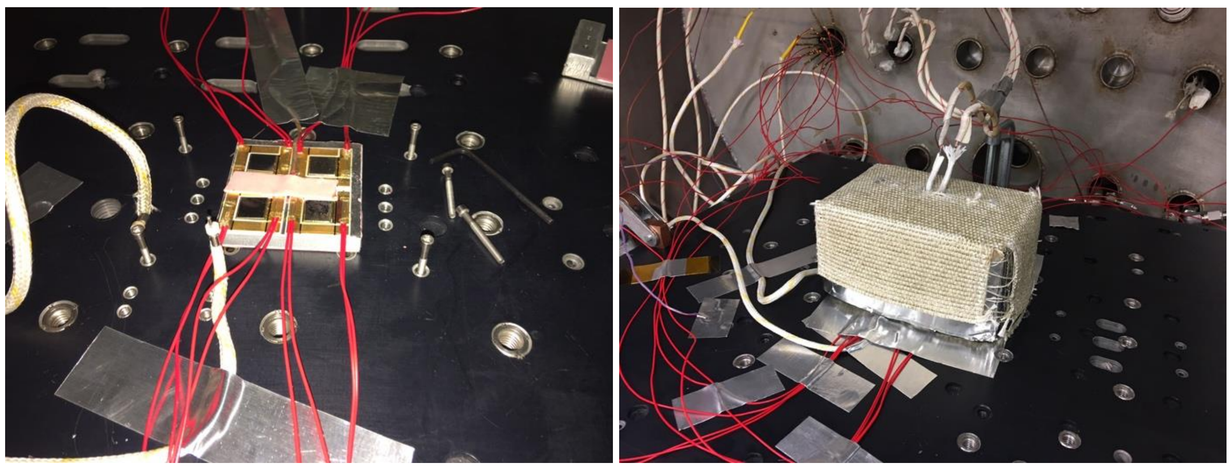

Figure 4: Testing the TPC cells in the TVAC chamber. The MLI is visible in the right image

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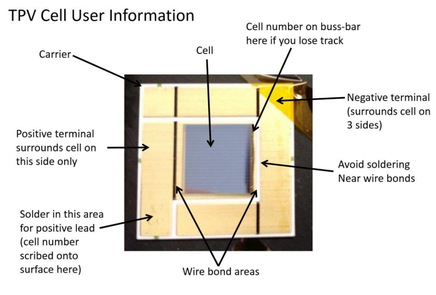

Publications:

Publications expected to follow

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