Development of TPV cells based on inverted epitaxial Indium Gallium Arsenide

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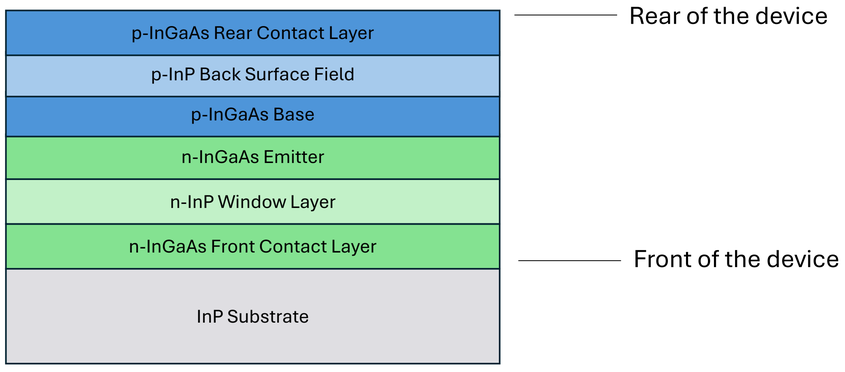
Motivation

- Latent Heat Thermophotovoltaic Batteries (LHTPVB) are a technology which allows storage of electricity in the form of latent heat at very high temperatures (>1000°C) and the conversion of this heat it back to electricity on demand using thermophotovoltaics (TPVs) [1].
- LHTPVB's are emerging as a promising for decarbonizing heavy industry to slow down the rate of global warming and transition to low carbon or net zero energy sources [2].
- A snap-shot of the development of the TPV generators based on inverted epitaxial Indium Gallium Arsenide (InGaAs) used for the heat-to-power conversion component of the technology is presented here.

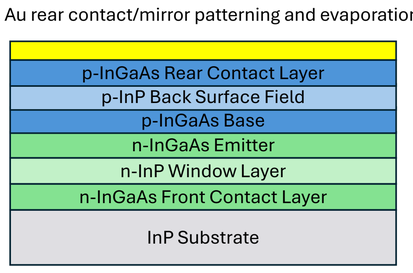
Methods – TPV Cell Fabrication

- Device fabrication begins with the following inverted epitaxial structure grown by MOVPE:

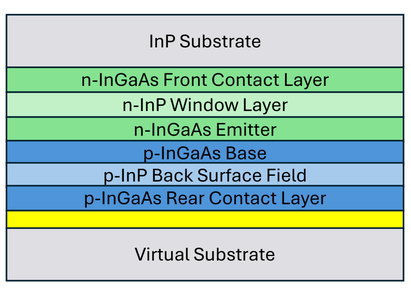


- The concept for the device fabrication process was developed by Geisz et al. for tandem metamorphic cells for concentrator solar photovoltaics and later adapted by Tervo et al. for InGaAs cells for TPV [3-5].

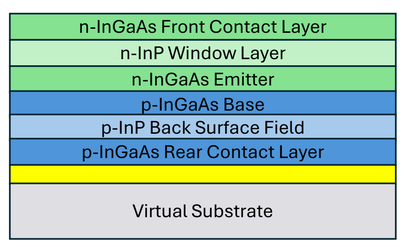
1. Au rear contact/mirror patterning and evaporation



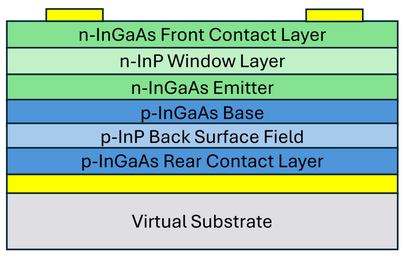
2. Bonding to virtual substrate using non-conductive epoxy



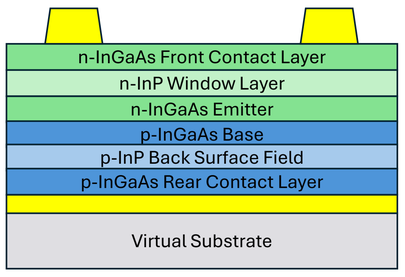
3. InP substrate removal via wet chemical etching



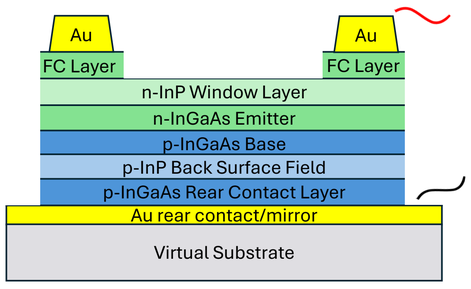
4. Au front contact patterning and evaporation



5. Growth of front contact via electrochemical deposition

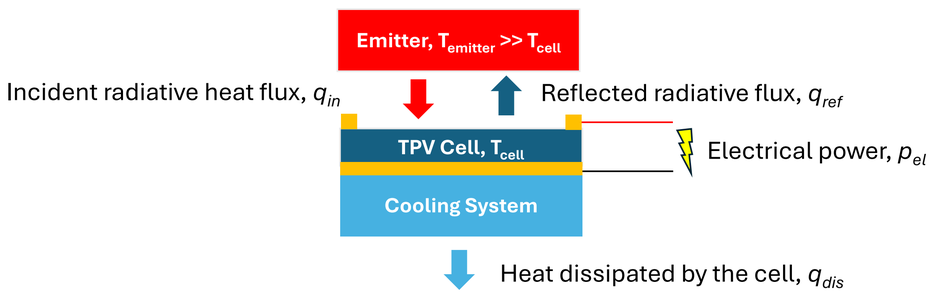


6. Mesa etching for device isolation



Methods - Characterization

- The energy balance for TPV systems is determined by the radiation exchange between the hot thermal emitter and the TPV cell in relatively close proximity :



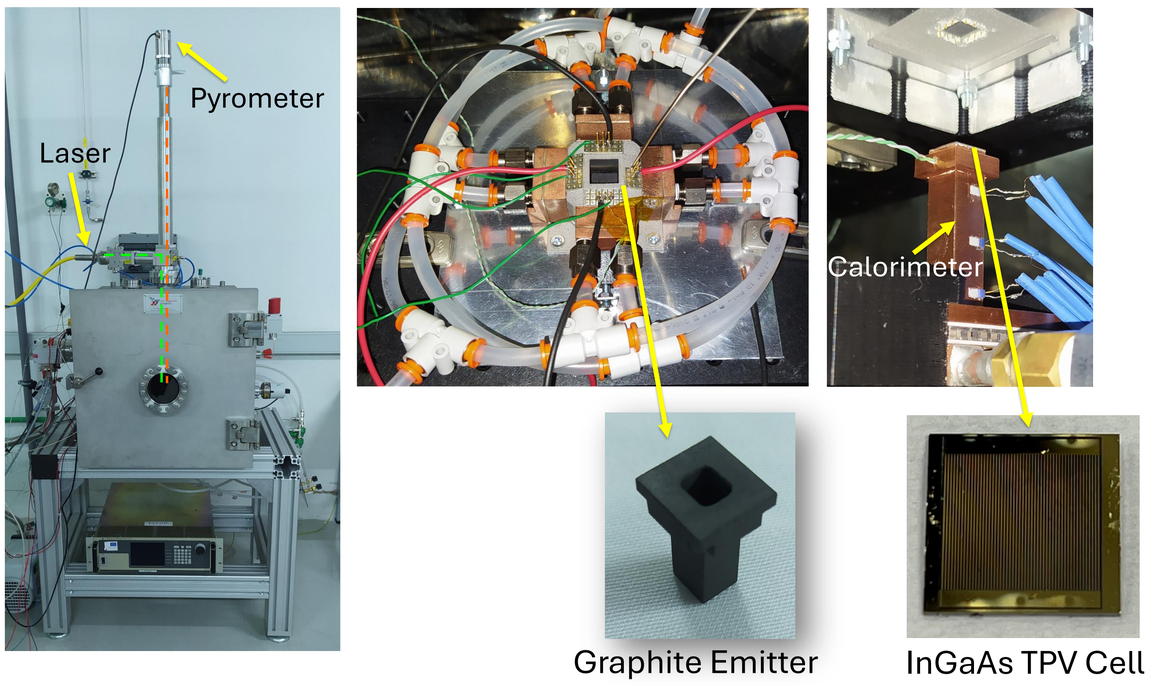
- TPV cell efficiency is defined as:

$$\eta_{TPV} = \frac{p_{el}}{q_{in} - q_{ref}} = \frac{p_{el}}{q_{abs}} = \frac{p_{el}}{p_{el} + q_{dis}}$$

- TPV cell efficiency can be measured experimentally using a home-made setup (shown to the right, López et al. [6]) that is capable of direct measurement of p_{el} (using the 4-wire method with a Keithley 2602B SourceMeter) and q_{dis} (using a calorimeter) at high view factors.

Top View

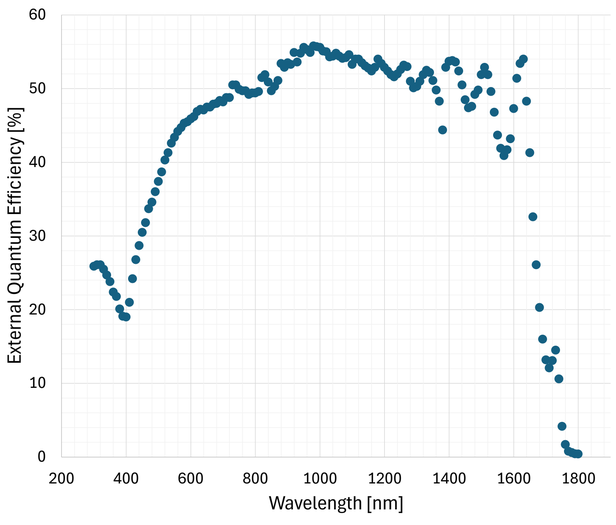
Bottom View



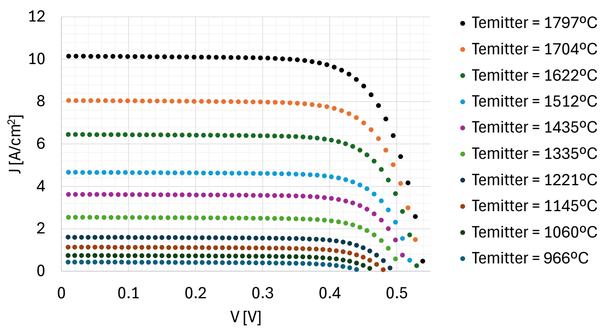
Results – Electrical and Optical Characterization

- A Fourier Transform Infrared spectrometer (FTIR) was used to measure the external quantum efficiency (EQE).
- Current-Voltage sweeps were performed in the TPV setup shown above with and without illumination to extract the fitted series and parallel resistances (R_s, R_p).
- Transmission Line Measurement (TLM) structures were fabricated with separate samples to characterize the sheet and contact resistances (R_{ss}, R_c).

EQE (No ARC)



JV Characteristics Under Illumination

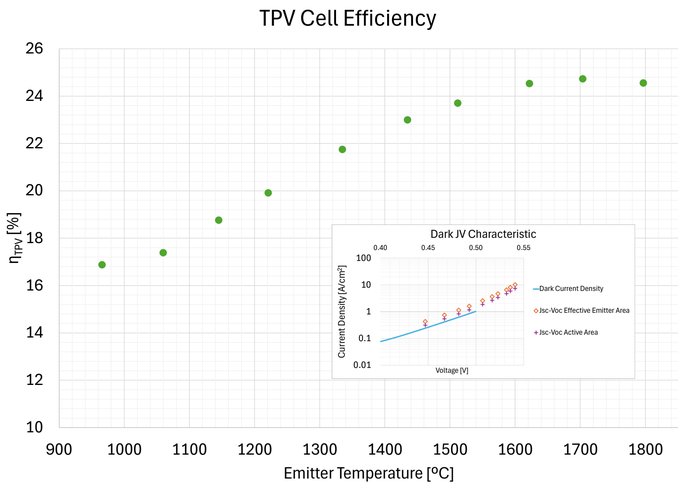


Fitted Parameter	Value
Series Resistance, R_s [mΩ*cm²]	1.9
Parallel Resistance, R_p [Ω*cm²]	12
Sheet Resistance, R_{ss} [Ω/□]	20.6
Contact Resistance, R_c [Ω/cm²]	1.97E-05

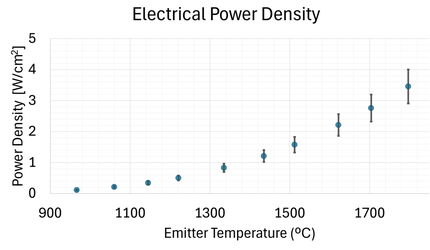
Results – TPV Efficiency Measurements

- In less than a year, a process was developed to fabricate TPV cells based on inverted epitaxial InGaAs with a rear mirror capable of achieving power densities as high as 3.5 W/cm² and nearly 25% conversion efficiency.
- A maximum TPV cell efficiency of 24.7% was measured at an emitter temperature of 1704 ºC.
- A maximum electrical power density of 3.46 ± 0.55 W/cm² was measured at an emitter temperature of 1797 ºC.

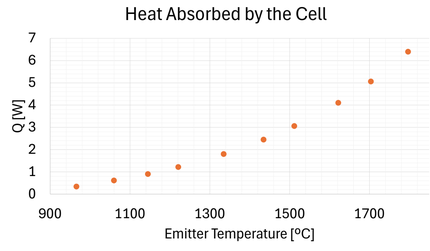
TPV Cell Efficiency



Electrical Power Density



Heat Absorbed by the Cell



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Acknowledgements

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