Ultra High Temperature Thermionic Sensor

parc
A Xerox Company

NETL Crosscutting Research Review Meeting

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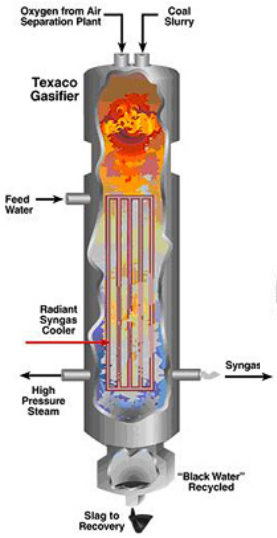
HEAT Sensor Project Goal

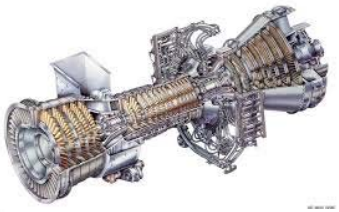
Harsh **E**nvironment **A**daptable **T**hermionics

- **Develop sensors that measure process parameters in:**
  - Harsh fuel, oxidizer and combustion product environment
  - High Temperature (750-1600 C)
  - High Pressure (up to 1000 psi)
- **Develop sensors that are wireless and self-powered**
  - Generate their own energy to operate and wirelessly transmit the data
  - Avoids wires that may be a reliability or inconvenience concern

Source: GE Energy



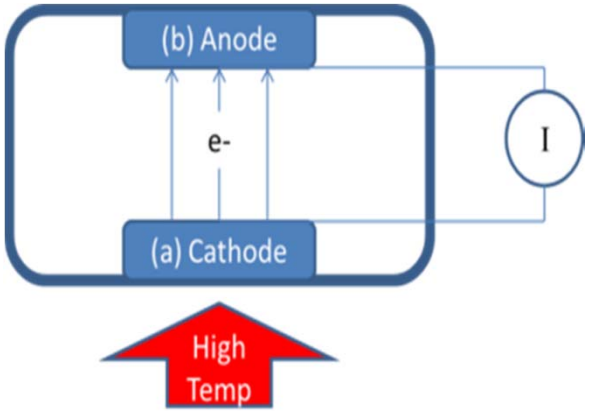
Source: GE Energy

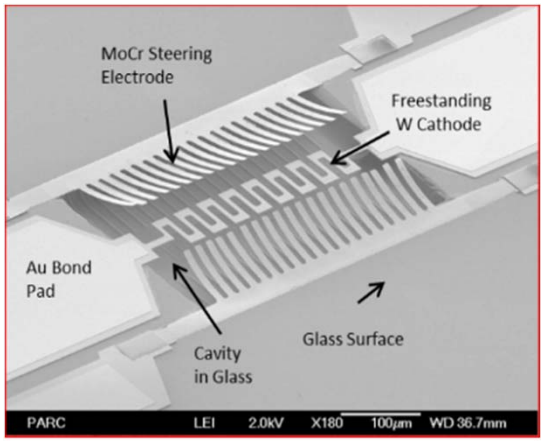


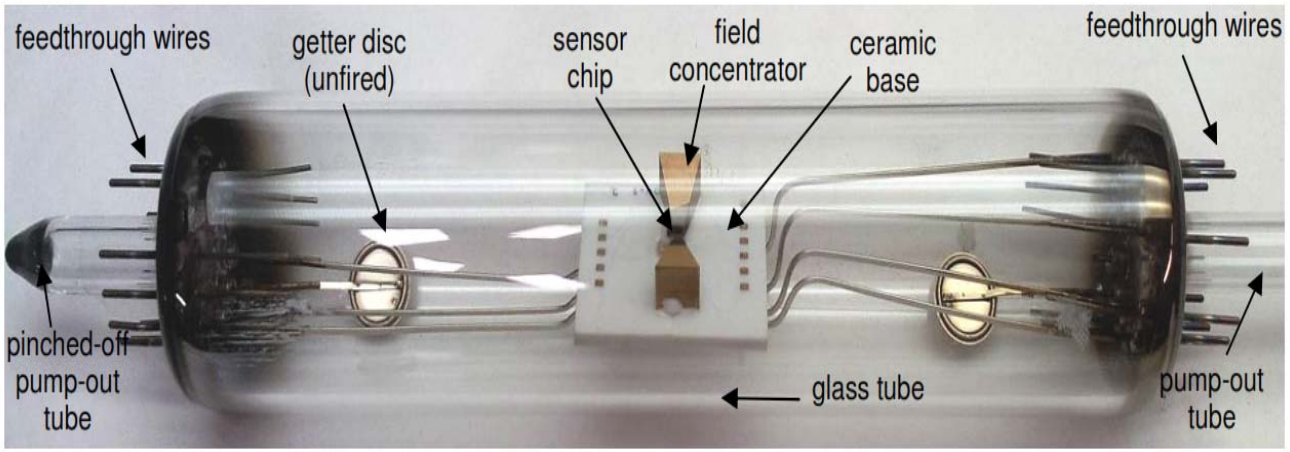
Thermocouple protection system for gasifiers (NETL website)

HEAT Sensor Project Concept

- Use Thermionic Materials as Sensors
  - Heat induced flow of electrons from a metal surface
  - Thermionic emissions occur at high temperature without need for external heater source
- La-W and W will be used based upon prior PARC work on a DARPA contract (E-FED)







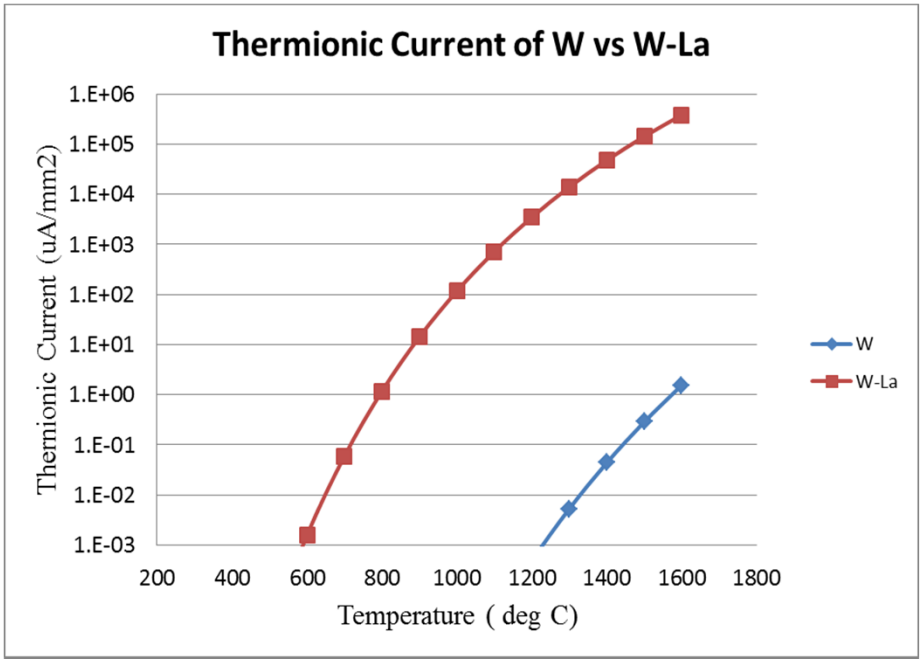
HEAT Sensor Project Plan

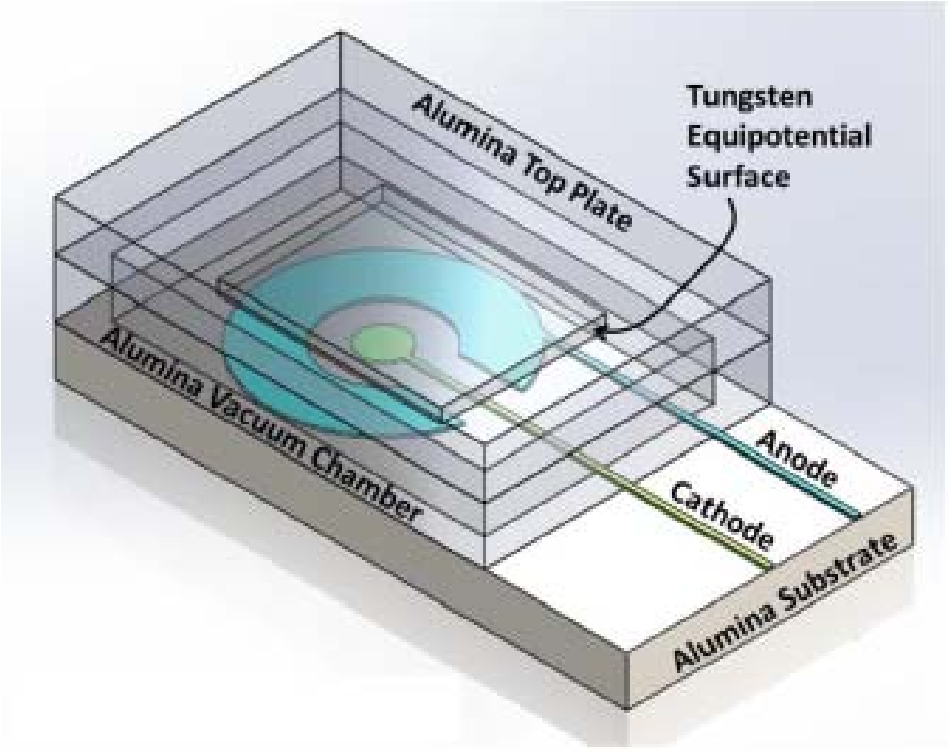
- Model and Pattern Thin Film Thermionic Layers
  - La-W (2.5 eV) and W (4.5 eV) for temperature and pressure sensing, and basic wireless circuit
  - BaO (1.0 eV) for power generation
- Develop Experimental System
  - Oven with Vacuum Capability
  - Electrical Interconnection to Sensor
  - Sensor Handling and Measurement
- Develop High Temperature Hermetic Package
  - Use High Temperature Co-Fired Ceramics (99.9% pure alumina)
  - Adhesive and Hermetic Sealant Development

Basic Temperature Sensor

Richardson's Law

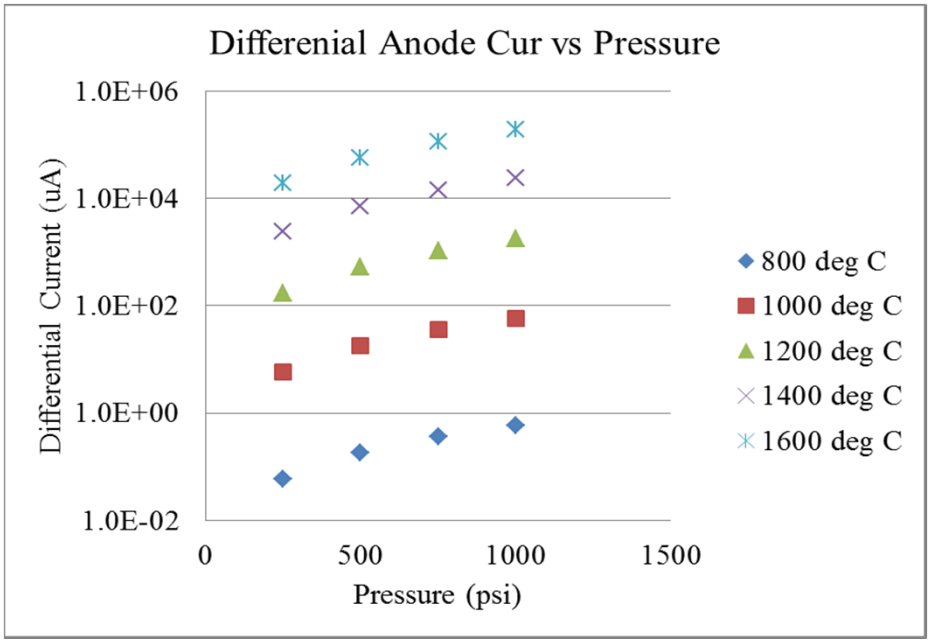
$$J = A_G T^2 e^{\frac{-W}{kT}}$$

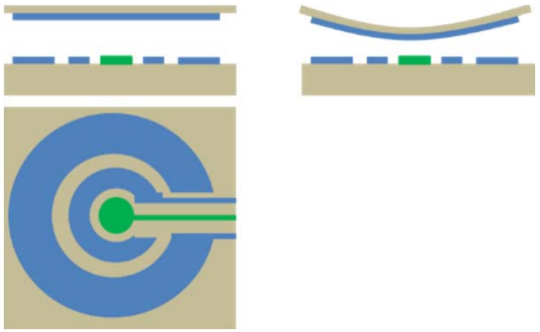


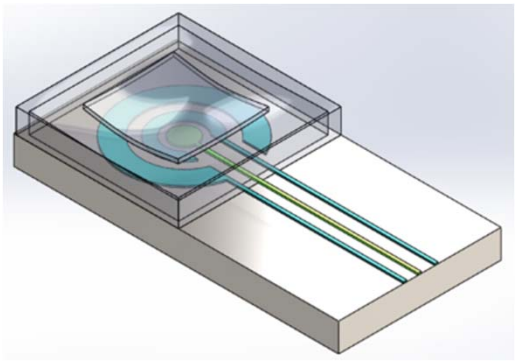


Pressure Sensor

Simulation

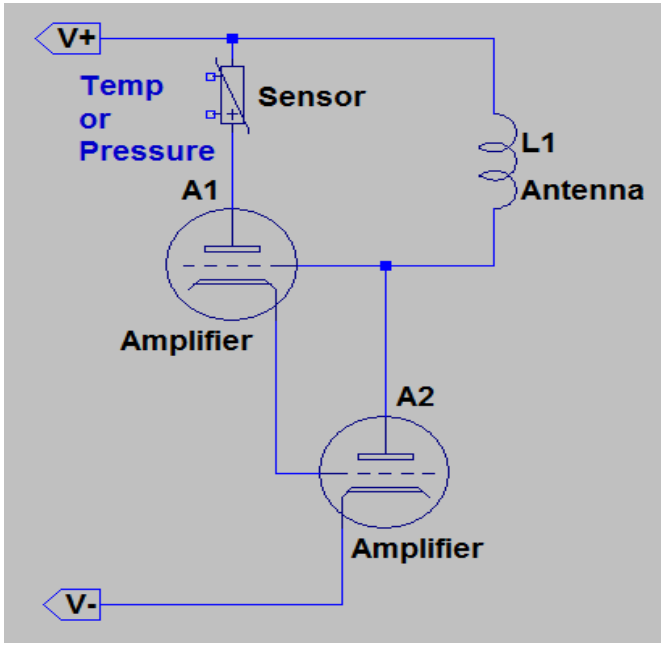




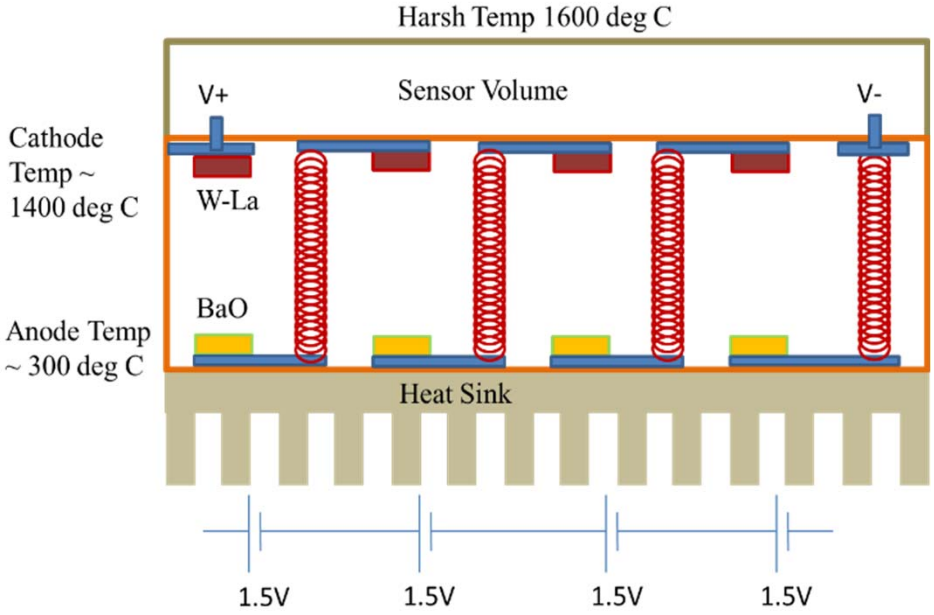


Autonomous Power & Wireless Transmission

Wireless Transmission Circuit Example



Power Generation Concept



Vacuum Oven

Voltage Source

Keithley Current Meter

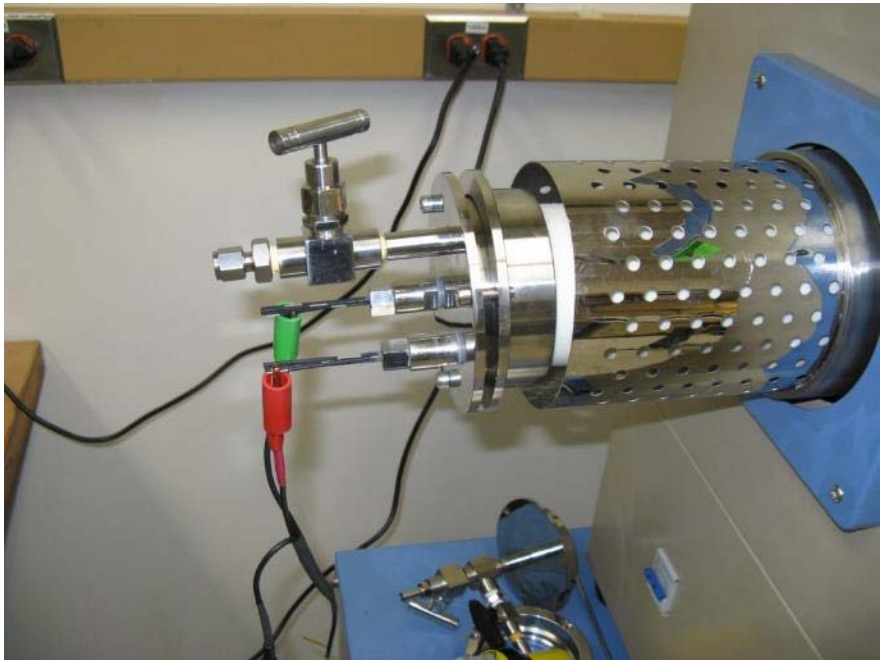
Turbo Pump (<1e-5 mbar)

Exhaust Line Port

Instrument Connection

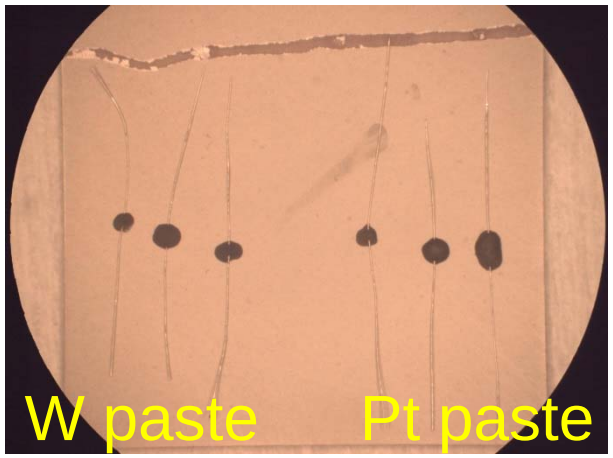
Flange with Pt Wire Connection
Up to 8 total connections

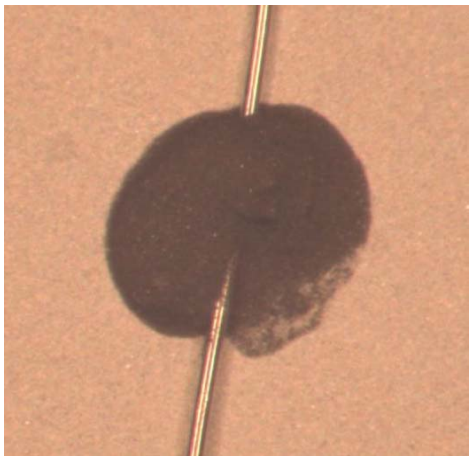
Flange Connected to Furnace Tube
and Measurement Leads

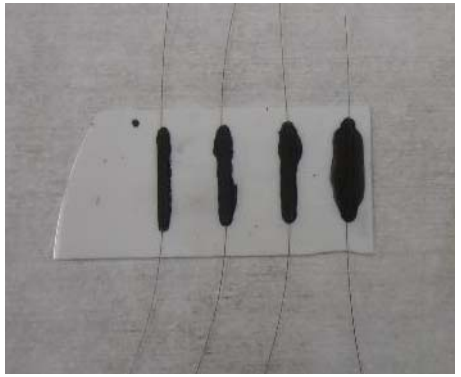


Wire Connection
Sensor Film/Package to Pt Wire

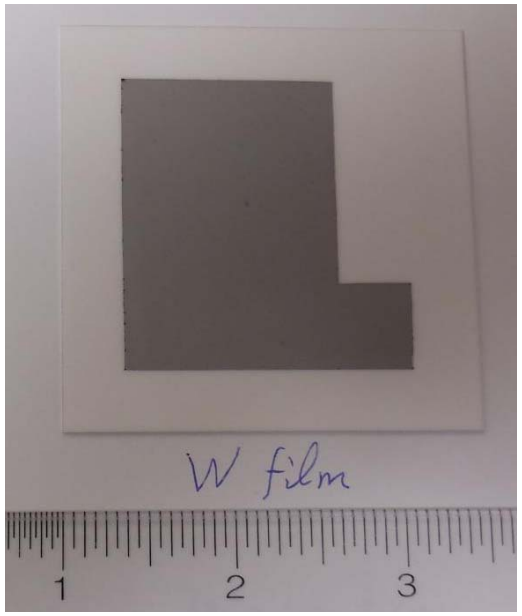
- W and Pt pastes were formulated using alumina adhesives and metal nanoparticles.
- Varying metal loading and application volumes were tested to determine interconnect reliability.
- Both the W and Pt paste worked well and survived temperature runs of 1400C.
- W paste will be used due to ease and cost

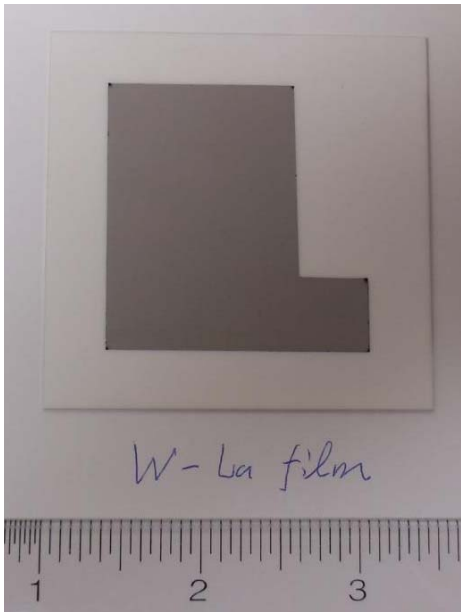






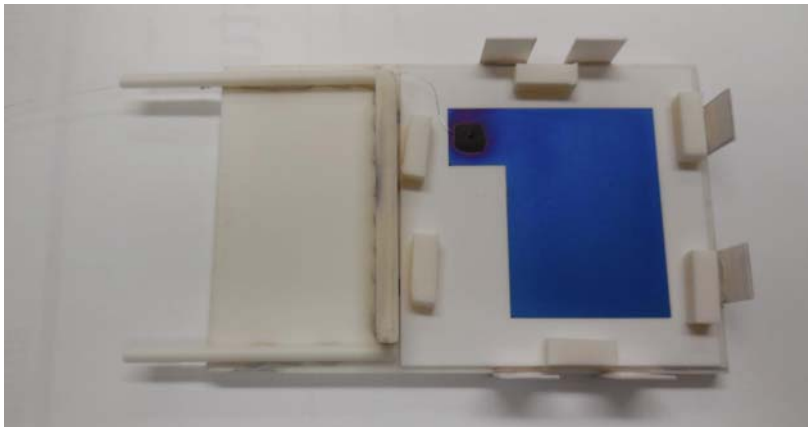
Thermionic Thin Films



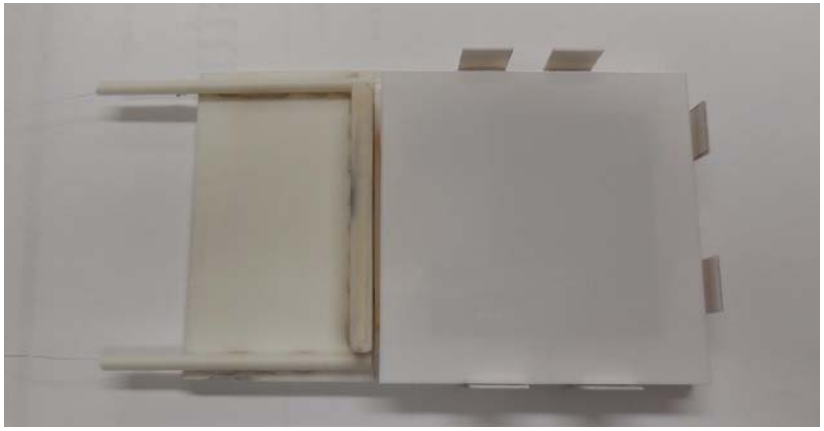


As-deposited W film and W-La film. The sheet resistance is 0.29 Ω/sq. for W film and 1.28 Ω/sq. for W-La film.

Ceramic Fixture for Initial Tests



Ceramic fixture for holding the bottom W film

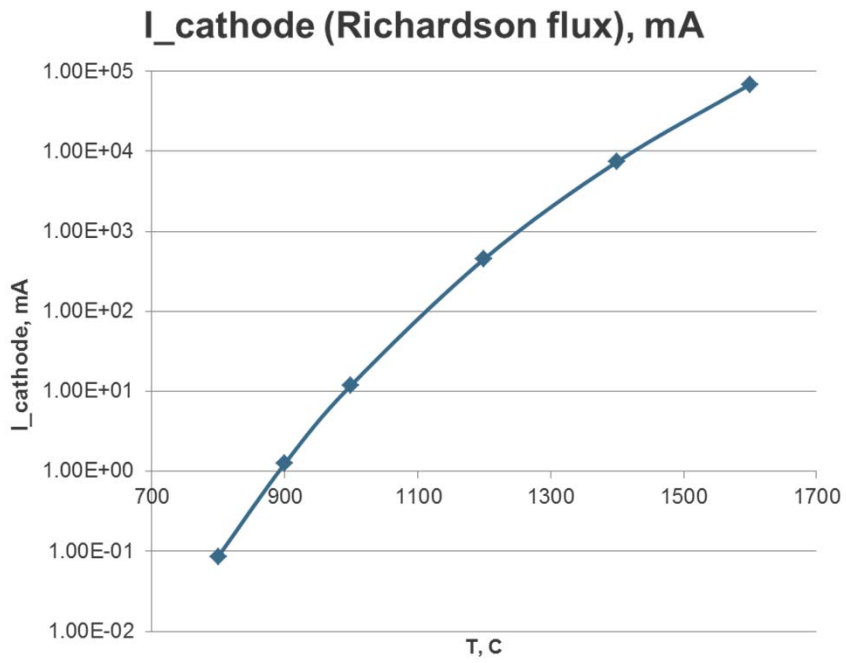


Initial Temperature Sensor Device

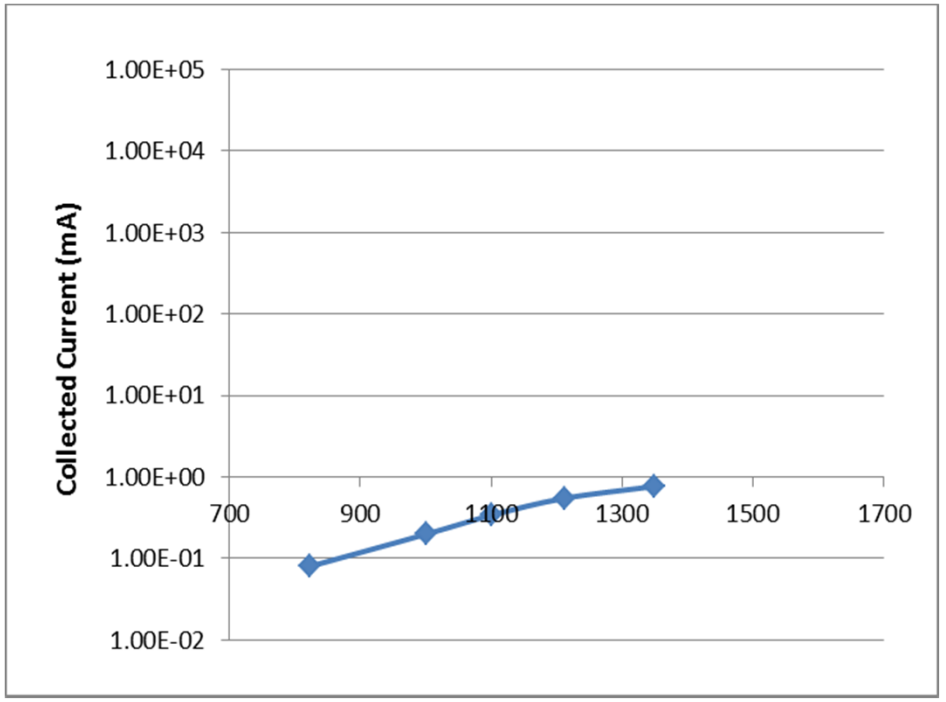
- Setup was put into the tube furnace.
- I-V curves at temperatures between 800 and 1350°C in vacuum were measured.

First Data from Thermionic Sensor Element

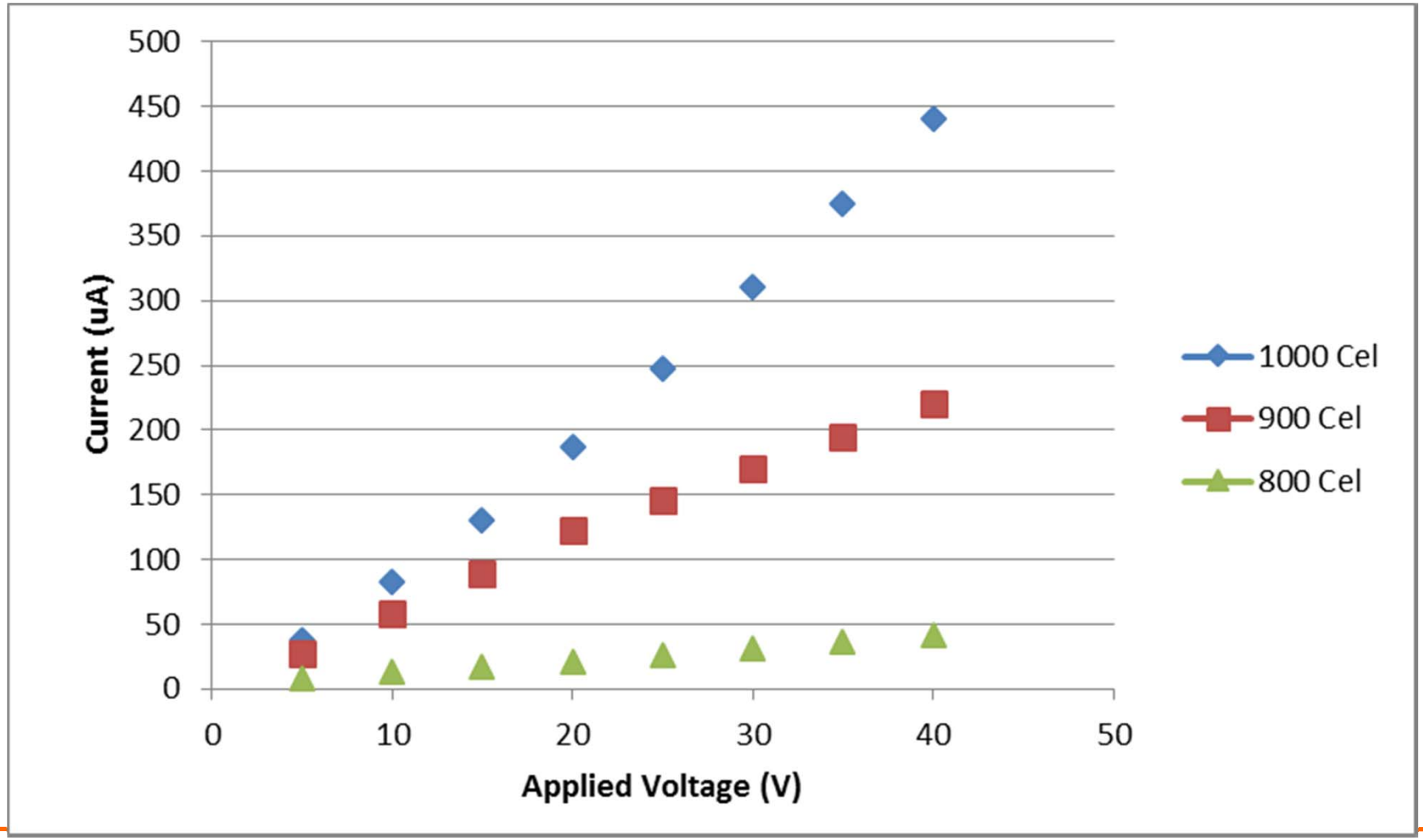
Simulation
Maximum Current Emitted



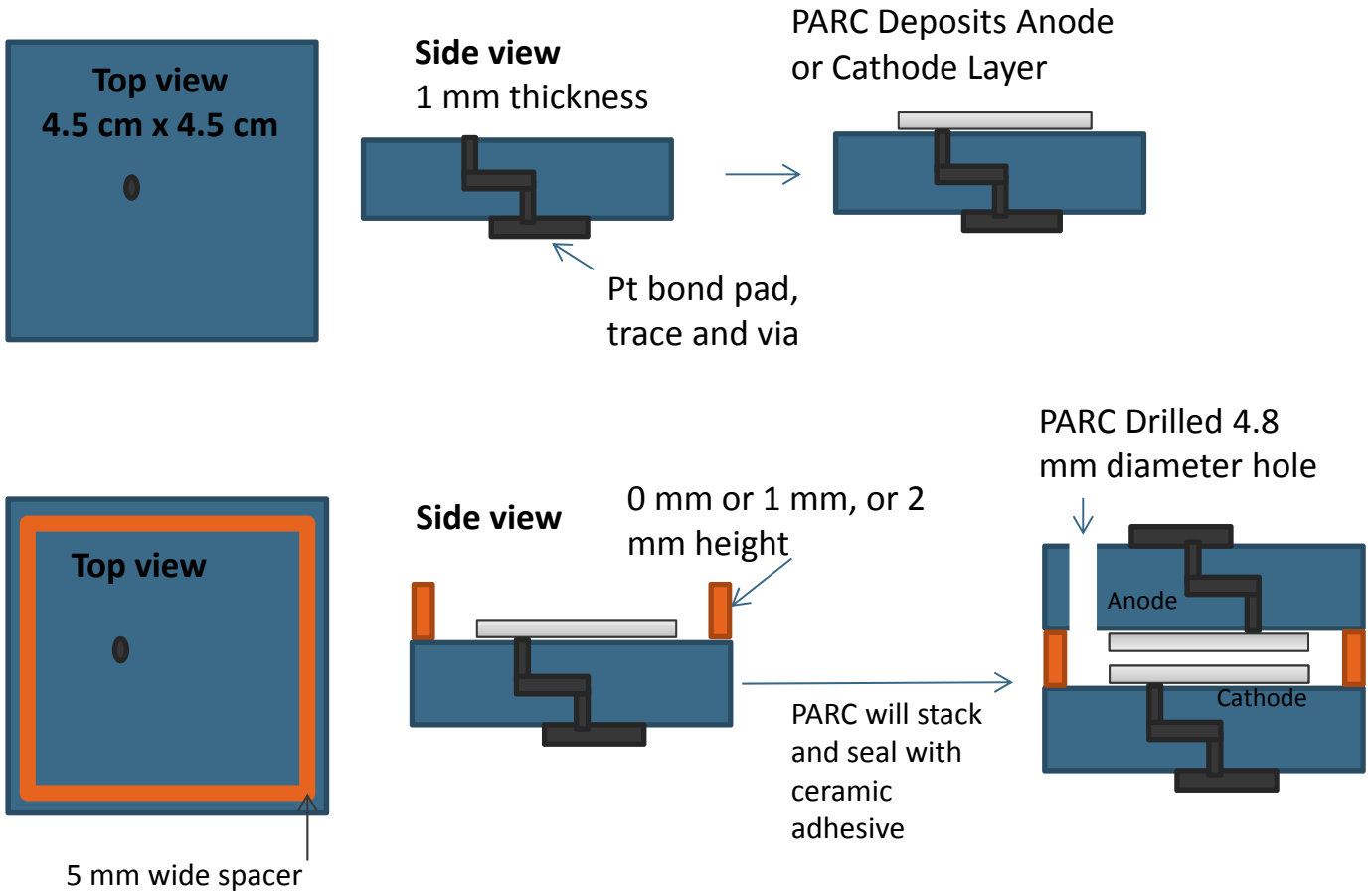
Data -- Collected Current
@ 5 mm gap, 25V



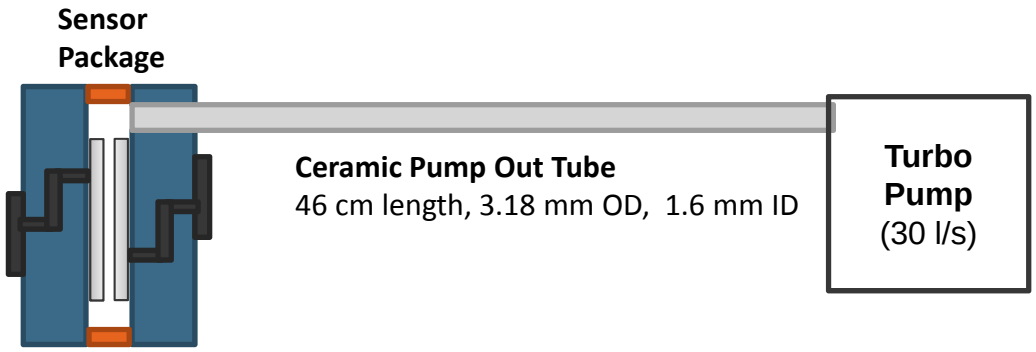
First Temperature Sensing Data from Thermionic Sensor

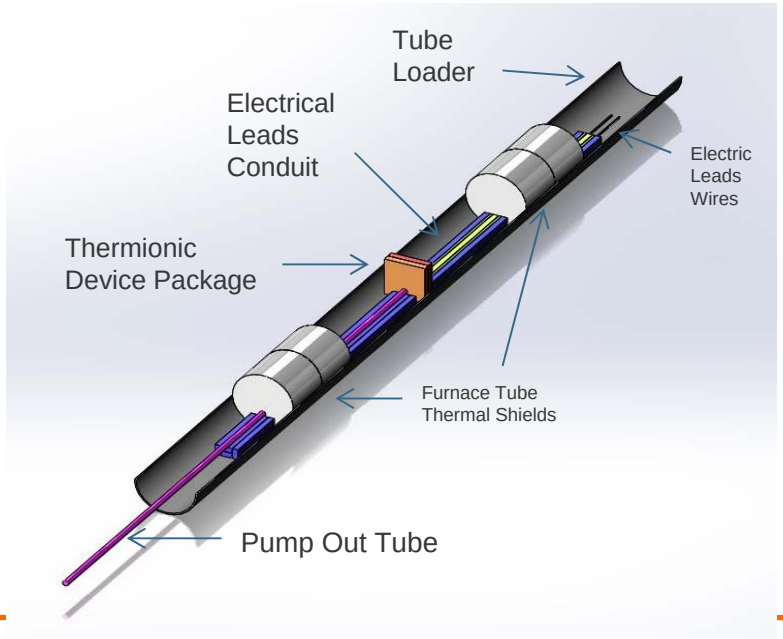


Thermionic HTCC Package Design

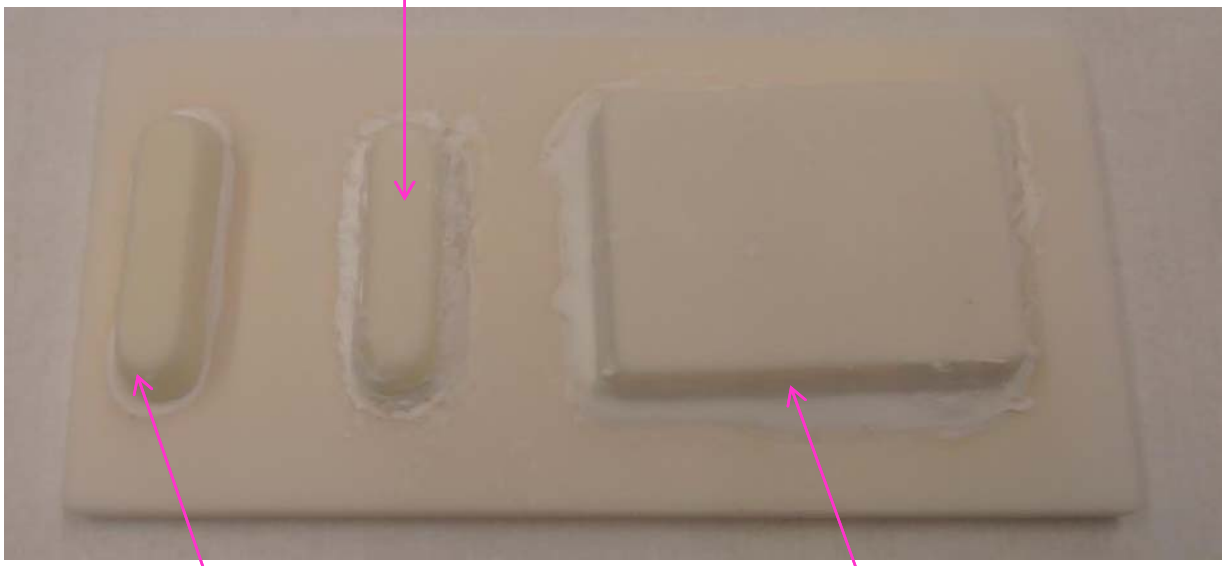


Oven Fixture Setup





Bonding and Sealing Experiments



Hermetic Seal Testing

- Encouraging initial results using Alumina Paste
  - Fired @ 1350C
  - <3.4e-4 mbar base pressure
  - Our target baseline pressure is 1e-4 mbar.
- Planned Improvements
  - Explore application method and firing procedure
  - Seal area and structure modification
  - Decrease paste particle size
  - Add CTE matched high temperature glass filler

Key Milestones

	Device Interconnect	Device Vacuum	Thin Films
Milestone 3 **Hermetic Seal**	None	Active pumping through tube	None
Milestone 4 **Temperature Sensor**	Pt wire with W paste + Pt via	Active pumping through tube	La-W and W
Milestone 6 **Pressure Sensor**	Pt wire with W paste + Pt via	Active pumping through tube	La-W and W
Milestone 9a **Self powered and wireless**	Pt wire with W paste + Pt via	Active pumping through tube	La-W, W, BaO
Milestone 9b **Self powered and wireless**	None	Self-contained vacuum with getter	La-W, W, BaO