

Ultra High Temperature Thermionic Sensor



NETL Crosscutting Research Review Meeting

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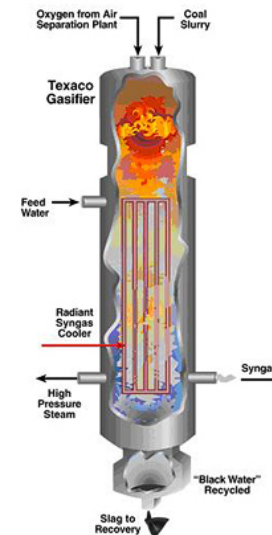
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HEAT Sensor Project Goal

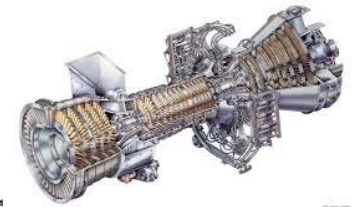
Harsh Environment Adaptable Thermionics

- **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



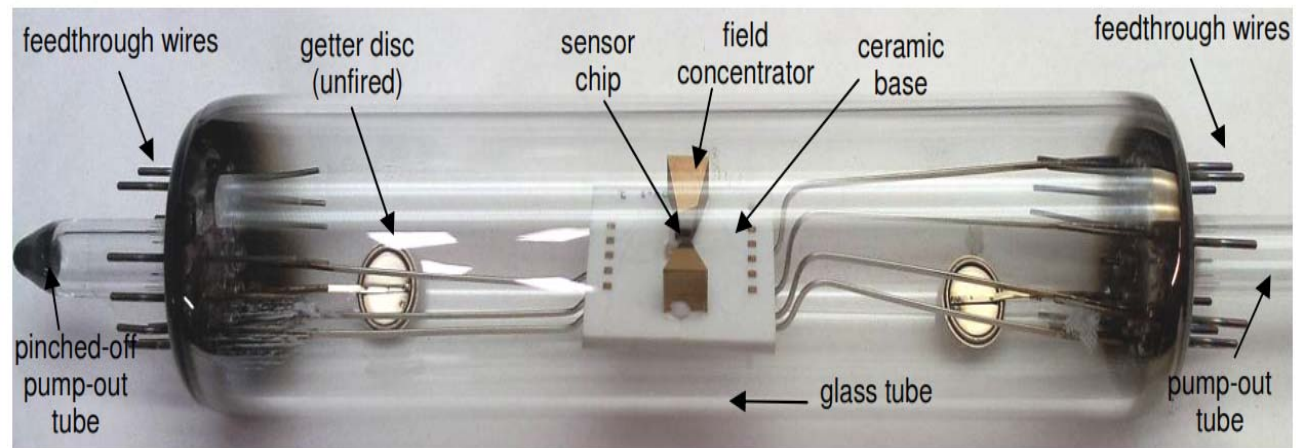
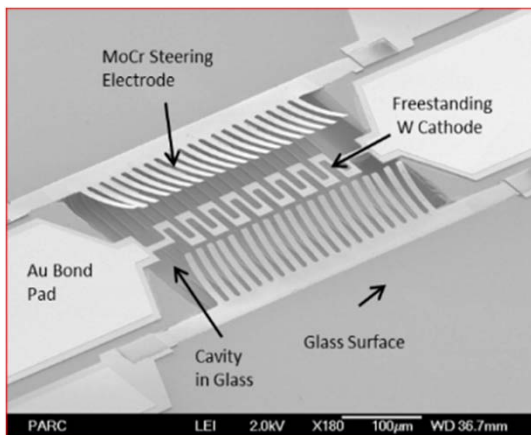
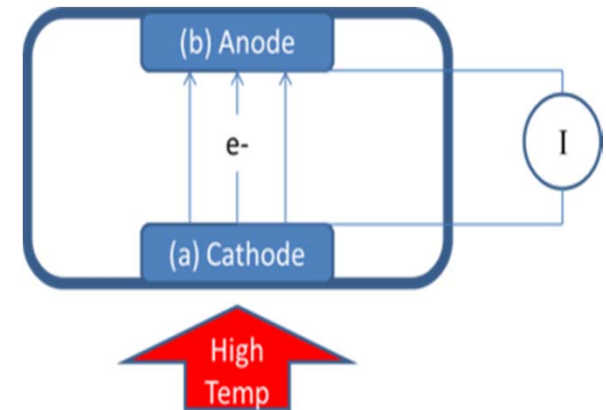
Source: GE Energy



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)



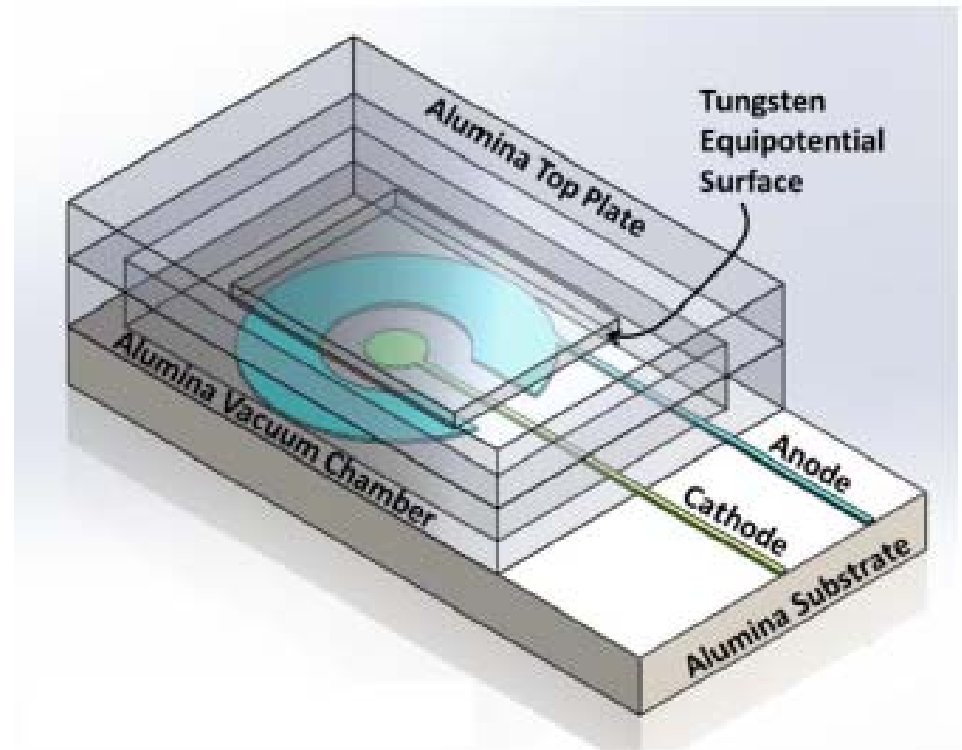
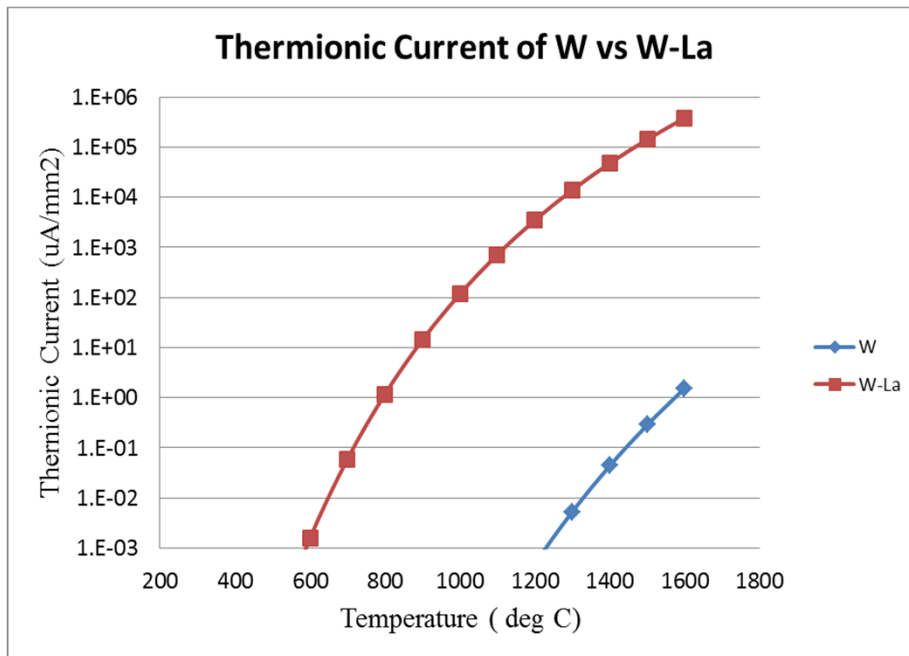
HEAT Sensor Project Plan

- 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

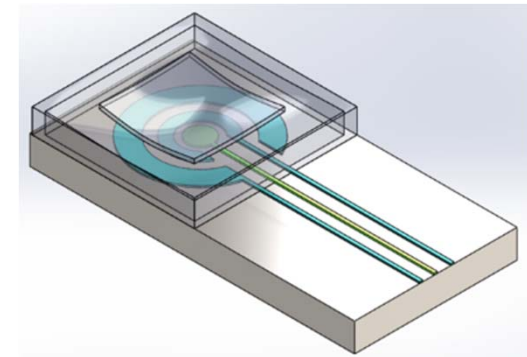
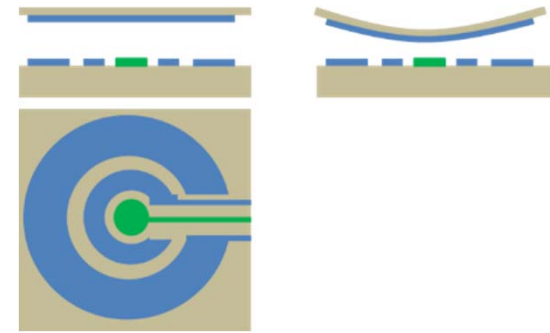
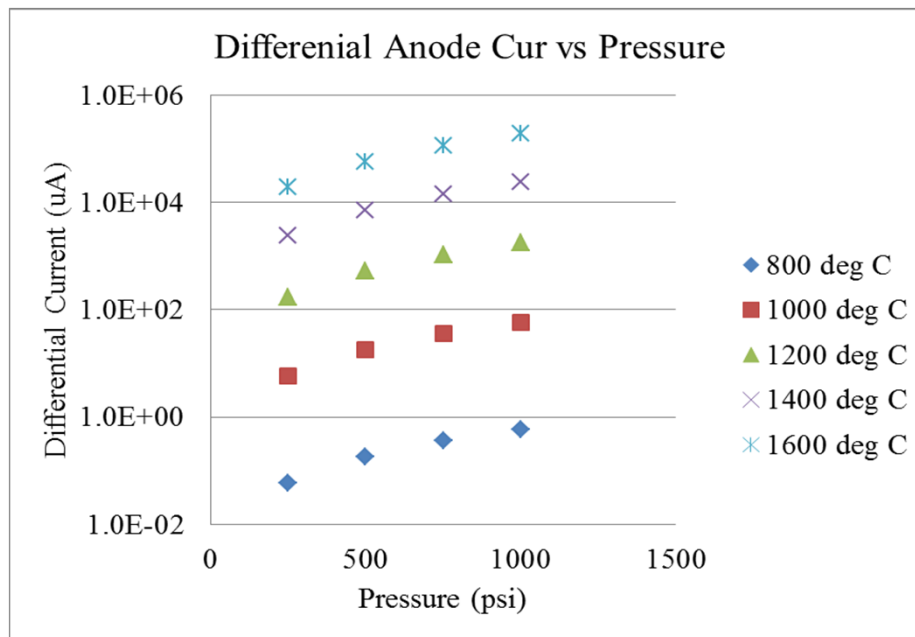
Richardson's Law

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



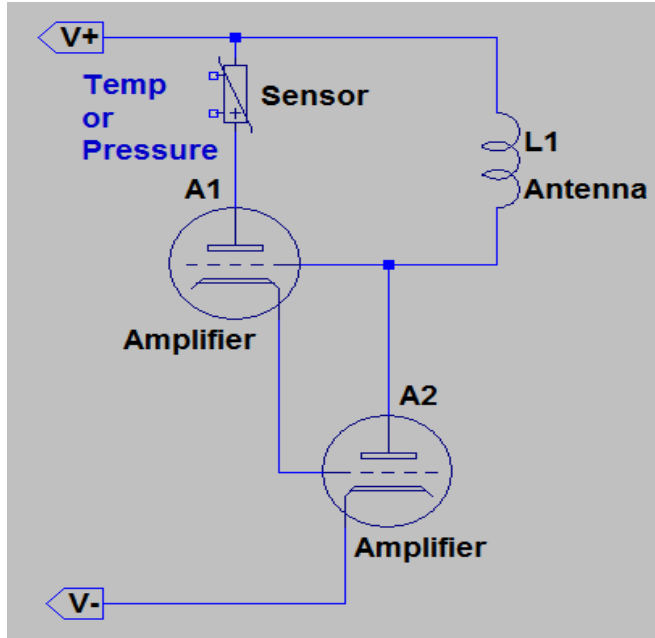
Pressure Sensor

Simulation

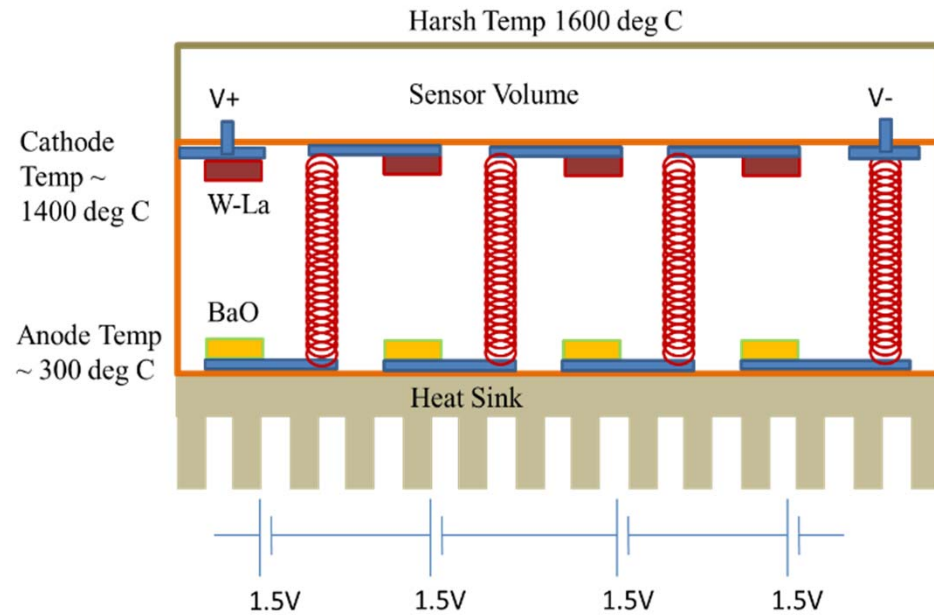


Autonomous Power & Wireless Transmission

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

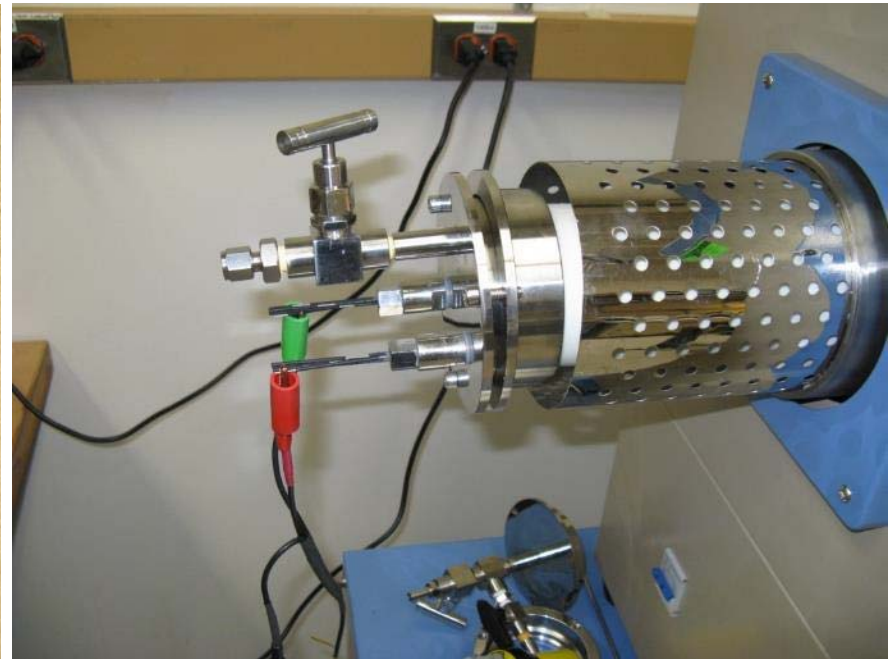


Pt Wire
100 um
diameter

Teflon
Shrink
Wrap

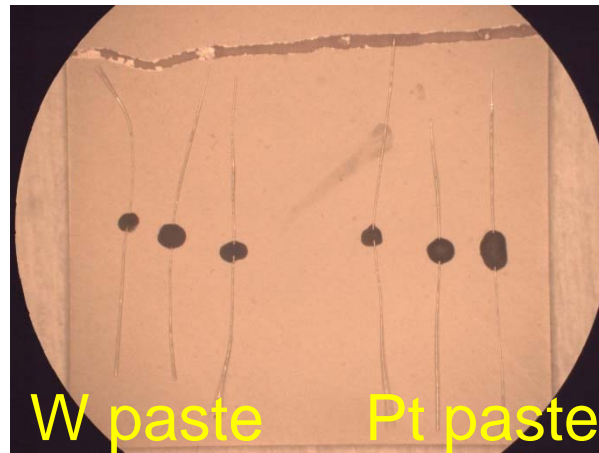
Gas Line
Port

Flange Connected to Furnace Tube
and Measurement Leads

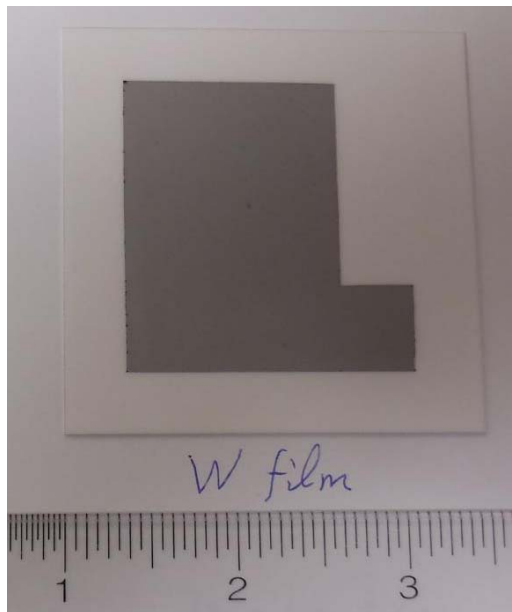


Wire Connection Sensor Film/Package to Pt Wire

- 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

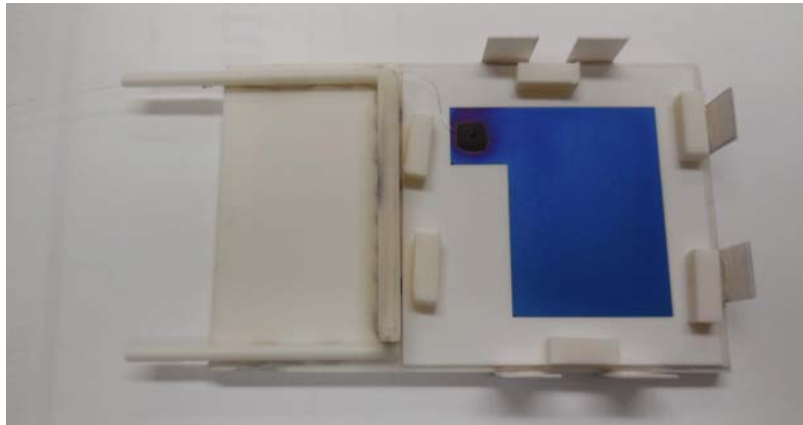


Thermionic Thin Films

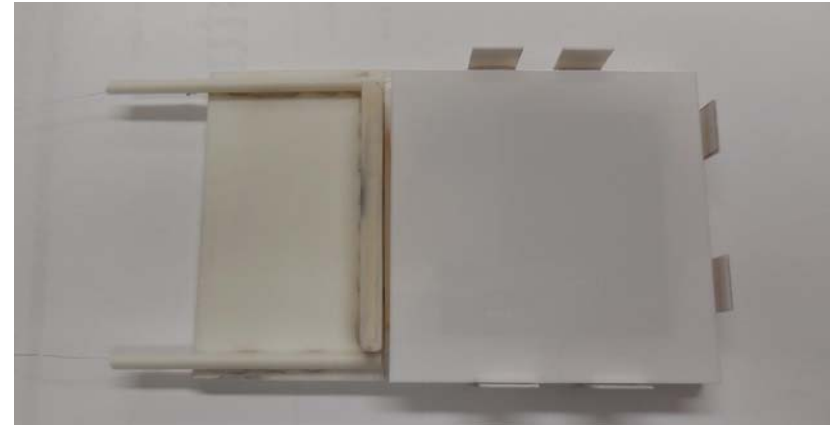


As-deposited W film and W-La film. The sheet resistance is $0.29 \Omega/\text{sq.}$ for W film and $1.28 \Omega/\text{sq.}$ for W-La film.

Ceramic Fixture for Initial Tests



Ceramic fixture for holding the bottom W film



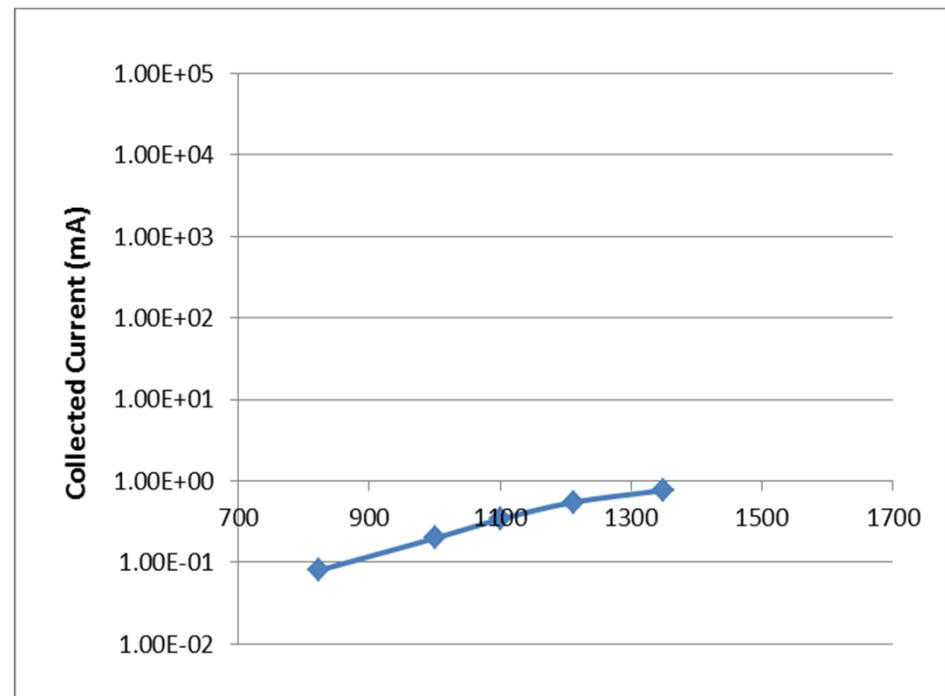
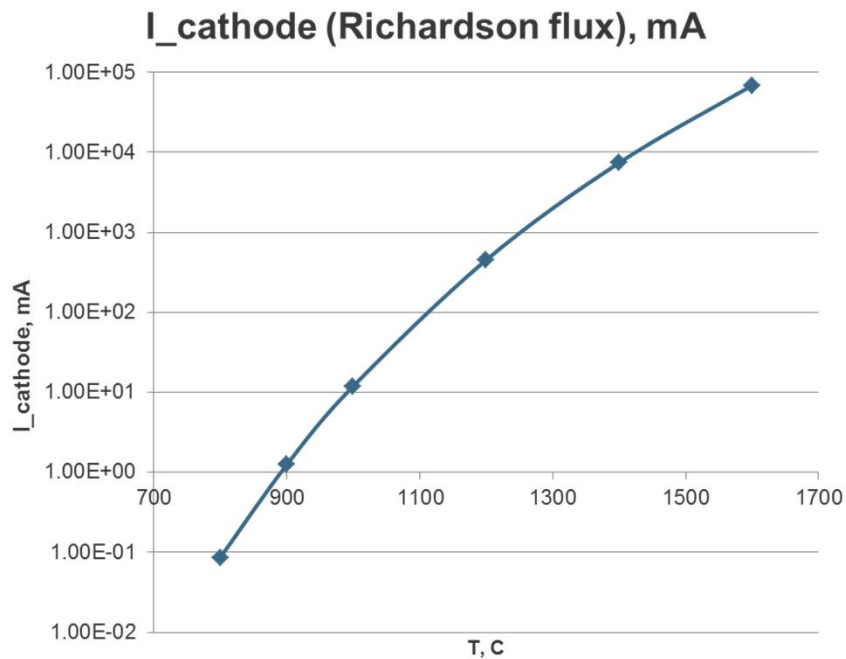
Initial Temperature Sensor Device

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

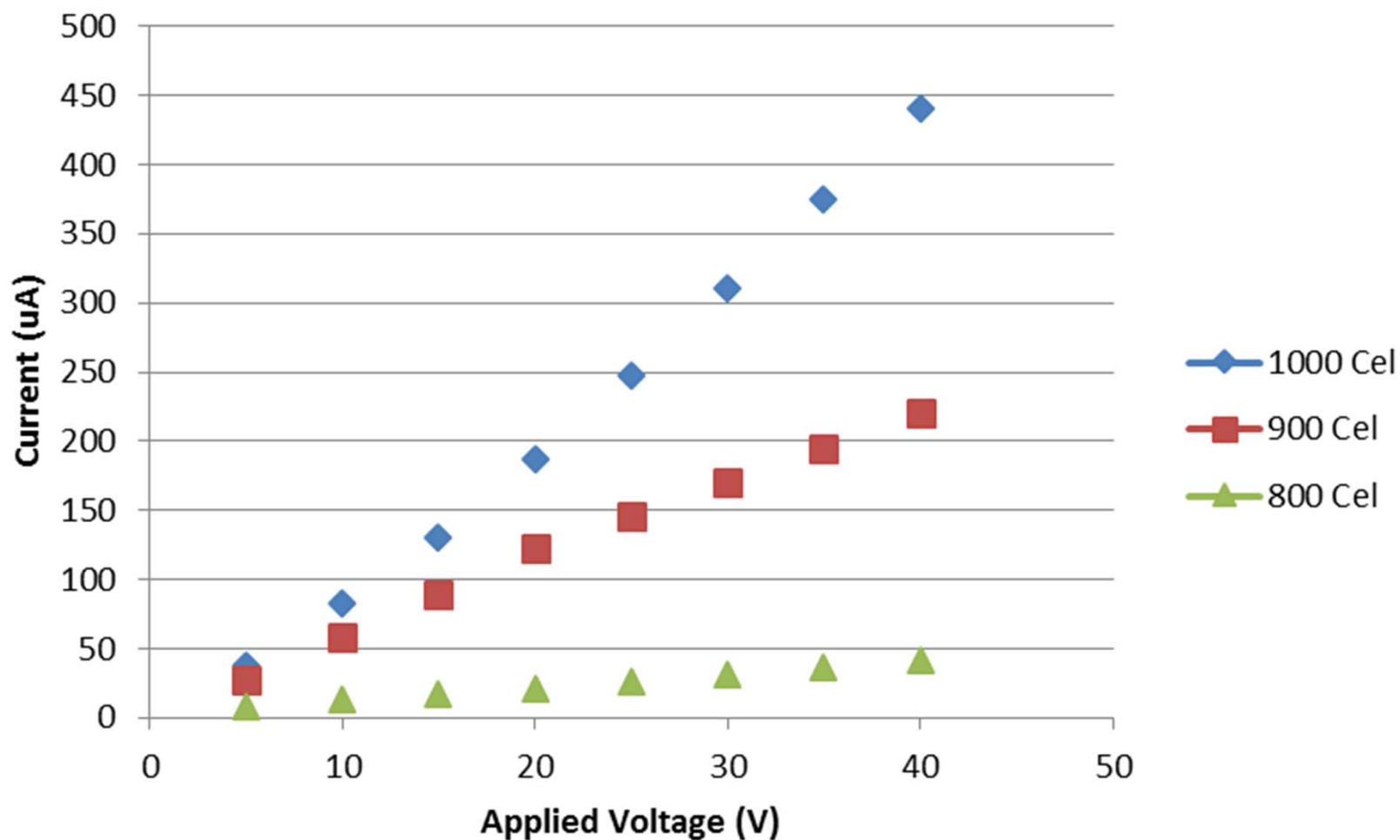
First Data from Thermionic Sensor Element

Simulation
Maximum Current Emitted

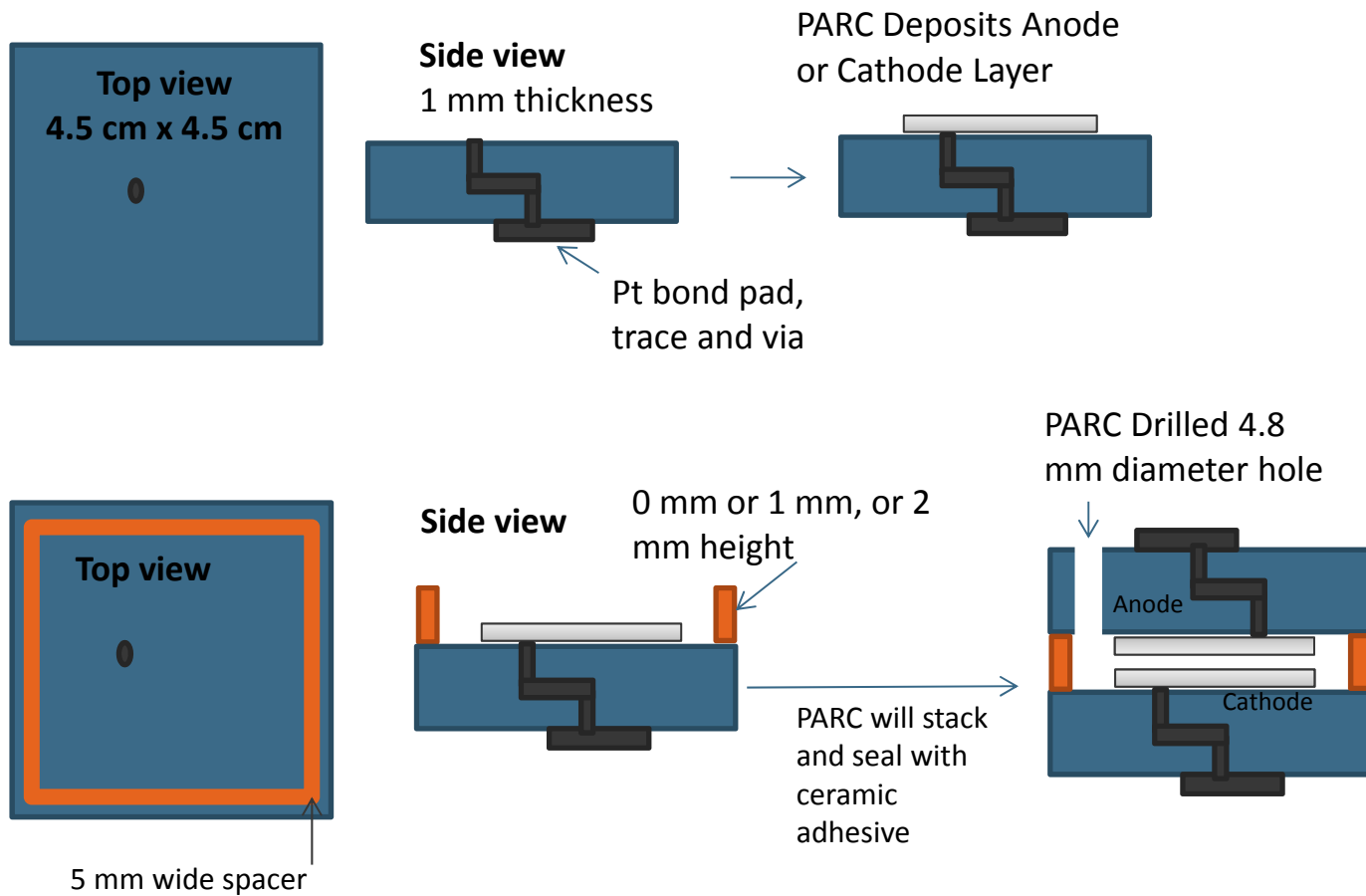
Data -- Collected Current
@ 5 mm gap, 25V



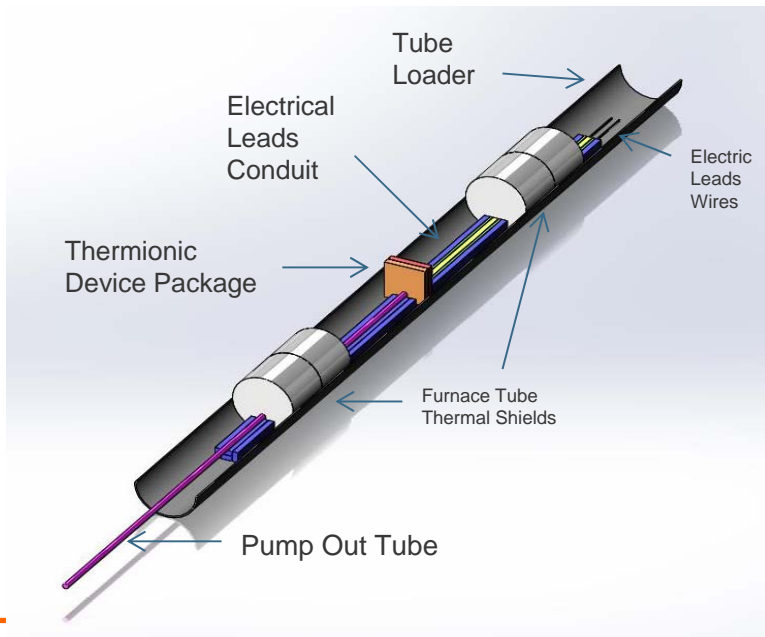
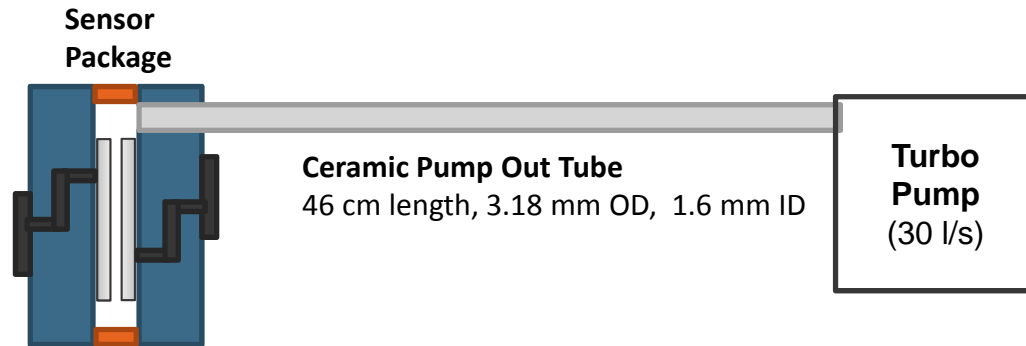
First Temperature Sensing Data from Thermionic Sensor



Thermionic HTCC Package Design

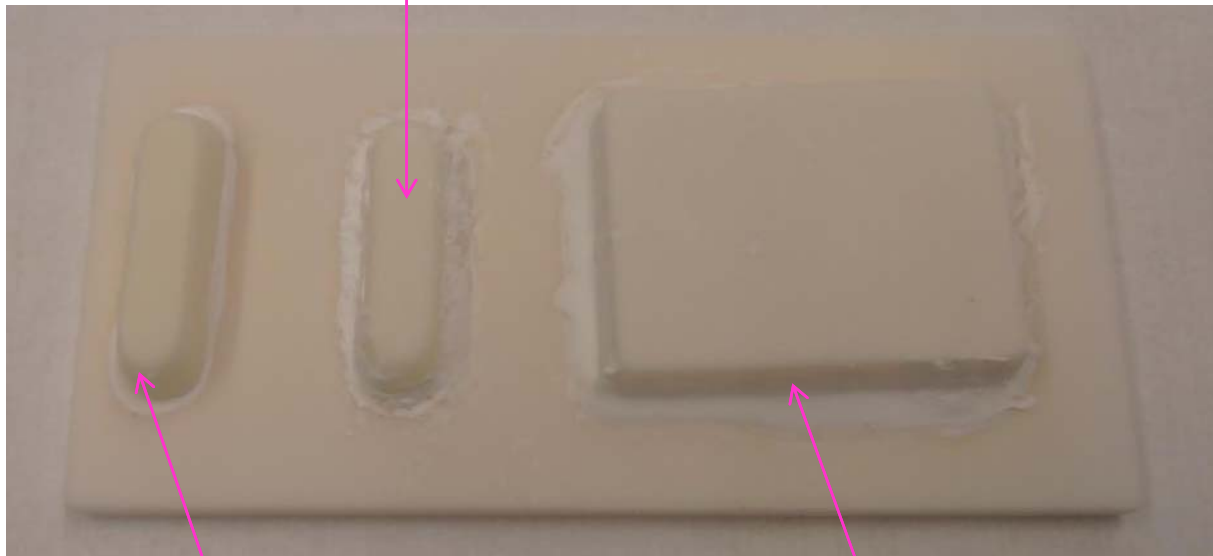


Oven Fixture Setup



Bonding and Sealing Experiments

Aremco adhesive
After 2 times at 1400°C/3hr, air



Cotronics adhesive
After 3 times at 1400°C/3hr, air

Cotronics adhesive
After 1400°C/3hr, air

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