Thin Film Sensors for Fission Surface Power

John D. Wrbanek

NASA Glenn Research Center

Cleveland, Ohio

2024 NASA Fission Instrumentation and Controls Workshop

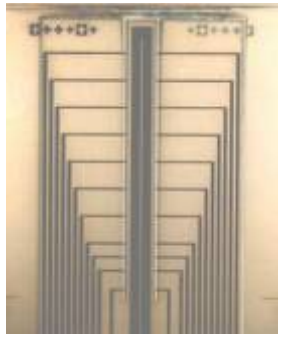
Cleveland, Ohio

August 20-22, 2024

Thin Film Physical Sensors for High Temperature Applications

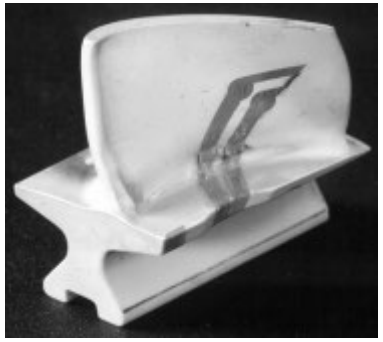
Advantages for temperature, strain, heat flux, flow & pressure measurements:

- Negligible mass & minimally intrusive (microns thick)
- Applicable to a variety of materials including ceramics
- Minimal structural disturbance (minimal machining)
- Intimate sensor to substrate contact & accurate placement
- High durability compared to exposed wire sensors
- Capable for operation to very high temperatures (>1000°C)



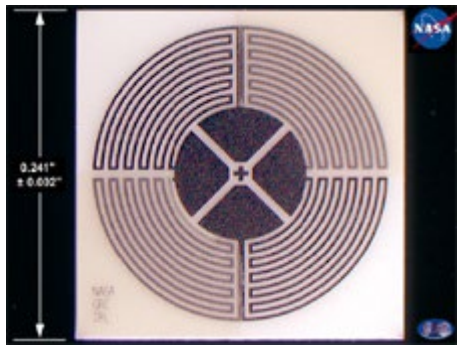
Flow sensor made of high temperature materials

Multifunctional smart sensors being developed

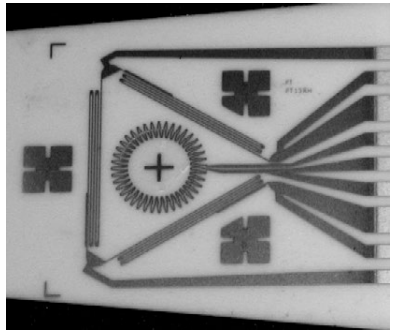


PdCr strain sensor to T=1000°C

Pt- Pt/Rh temperature sensor to T=1200°C



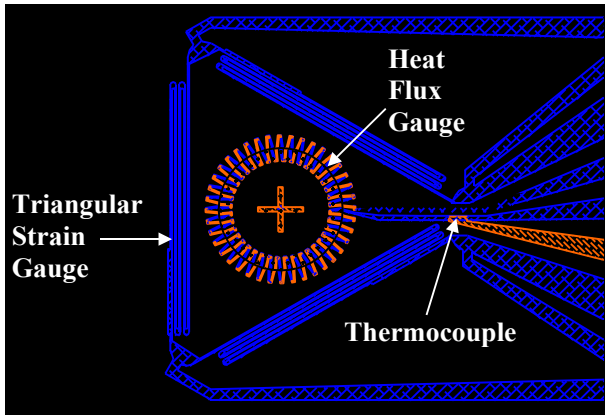
Heat Flux Sensor Array to T=1000°C



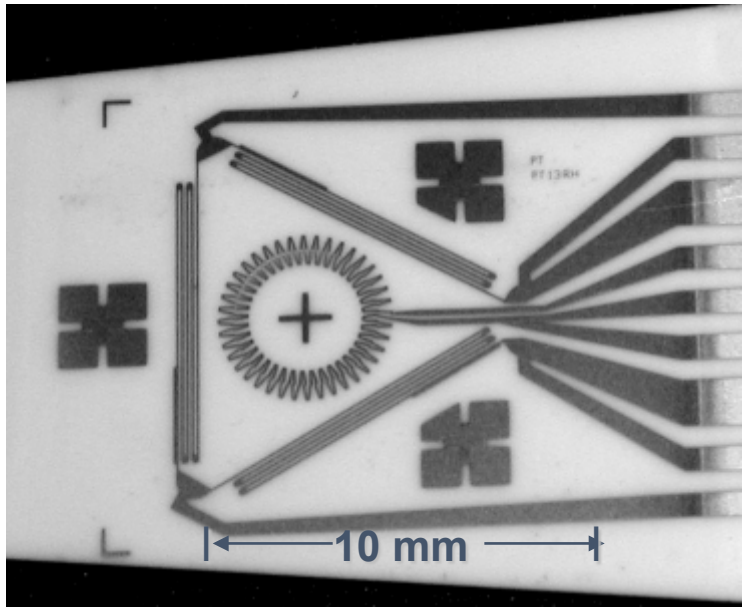
Multifunctional Sensor Array

Multi-Functional Sensor System

- Multifunctional thin film sensor designed and built in-house
- Temperature, strain, and heat flux with flow all one the same microsensor
- Enables measurements on component surfaces, and reduces boundary layer trip on metals compared to wires or foils
- Weldable shim designed to simplify sensor mounting
- Dynamic measurements demonstrated in lab



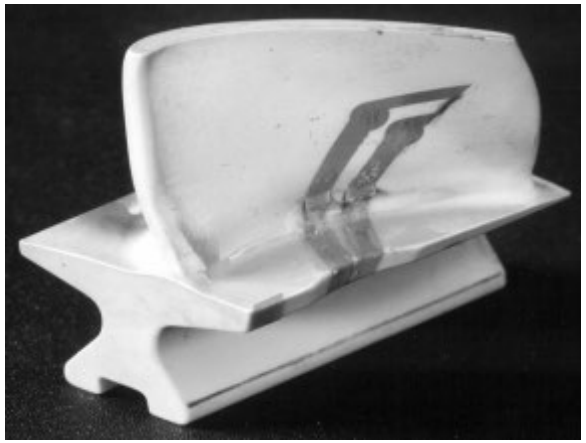
Schematic of Multifunctional Sensor



Multifunctional Sensor Prototype

High Temperature Strain Sensor Technology

- High temperature strain sensors developed based on PdCr
- Thin film gauge operated to 1100°C, compared to 700°C maximum of the commercially available technologies
- Survived fatigue tests at ±2000με up to 700Hz and 1000°C for a million cycles
- Dynamic measurements repeatable to ±10% over entire range with temperature compensation
- The gauges also demonstrated on SiC/SiC CMC components in a jet-fueled burner rig at 1100°C
- Gauges implemented to study fatigue characteristics for disk material

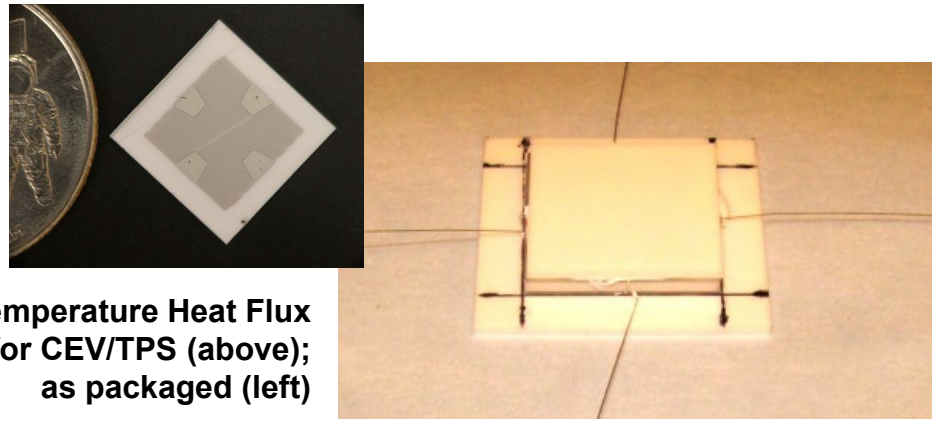


PdCr thin film gauge applied on a ceramic turbine blade

PdCr thin film strain gauge applied to a material sample for disk life fatigue testing

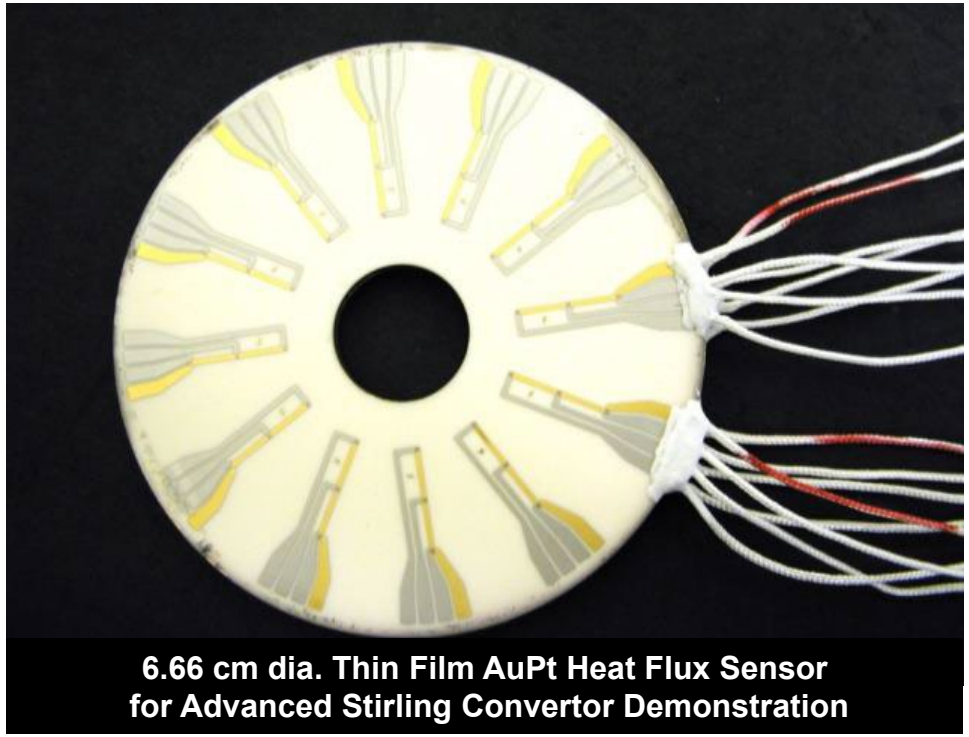
Heat Flux Sensor Applications

- High Temperature Heat Flux Sensors packaged and delivered to GRC Seals Group for CEV/TPS Heat Shield Interface Seal Studies at ARC



High Temperature Heat Flux Sensor for CEV/TPS (above); as packaged (left)

- High Temperature Au-Pt Heat Flux Sensors fabricated and delivered to GRC Advanced Stirling Development Group for direct measurement of thermal to electrical conversion efficiency in Advanced Stirling Convertor Units



6.66 cm dia. Thin Film AuPt Heat Flux Sensor for Advanced Stirling Convertor Demonstration

Thin Film Thermocouple Engine Testing

OBJECTIVE

- Enable improved dynamic temperature measurements at higher temperatures using thin film sensor technology

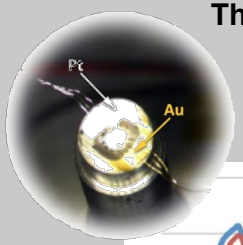
APPROACH

- Thin film sensors have negligible mass, are minimally intrusive, and can be applied to a variety of materials including ceramics
- Two high temperature prototype thermocouple probe designs fabricated and demonstrated
- Each sensor probe design demonstrated different thin film thermocouple types and packaging approaches

SIGNIFICANCE

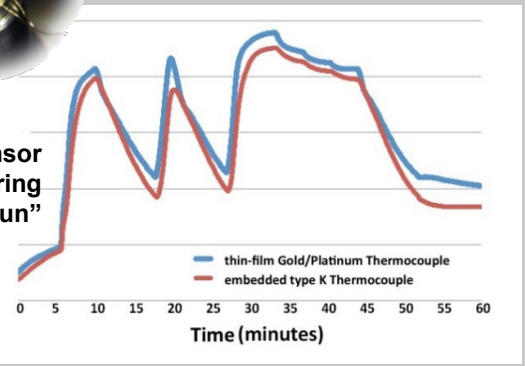
- Operation of thin film thermocouple sensor prototypes validated as installed in bleed-air borescope ports
- Sensors tracked dynamic engine temperature changes through multiple power cycles with faster response than embedded thermocouples
- Data included monitoring VAE performance trends
- Tracked performance changes were observed elsewhere in engine
- Application not limited to bleed-air borescope ports
- Part of information fusion to better understand the overall health state of the engine

VIPR 2 Design: Metal Probe / Au-Pt Thermocouple

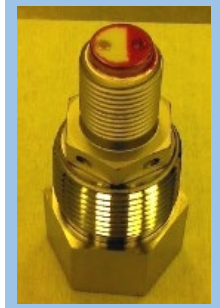


Sensor tip with 0.003” wires attached to deposited thin films

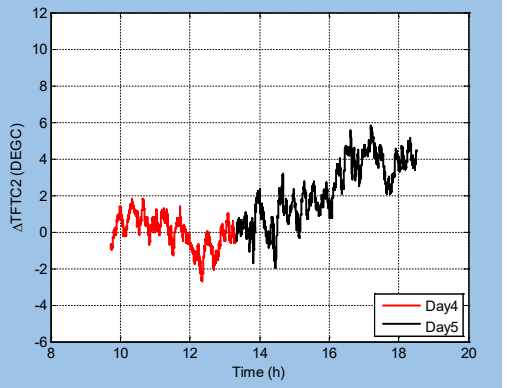
Thin Film Sensor Operation During “Green Run”



VIPR 3 Design: Spark Plug / Pt-Pd Thermocouple

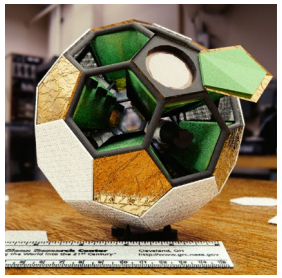


Thin film deposition processing on “Spark Plug” sensor tip



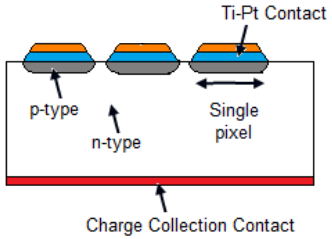
Thin Film Sensor Data: Volcanic Ash Runs Day 4-5

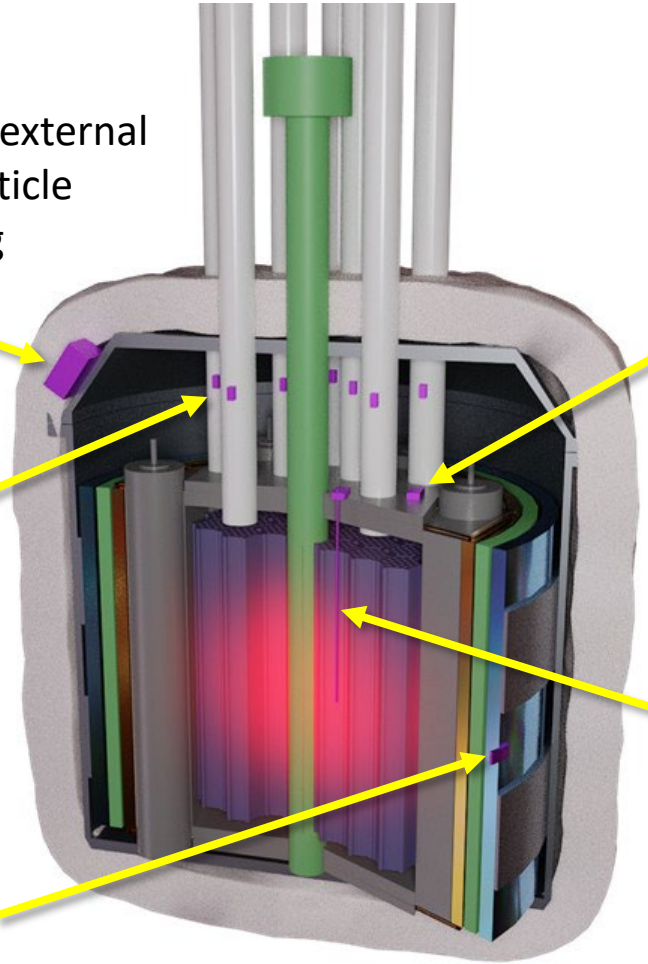
GRC Physical Sensing Technology for Reactor Instrumentation & Controls



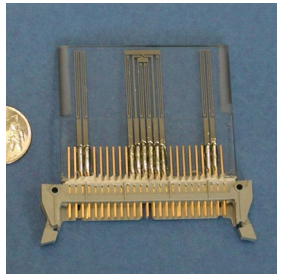
Low-noise external charge particle monitoring

High Temperature Fast Neutron Flux Monitor

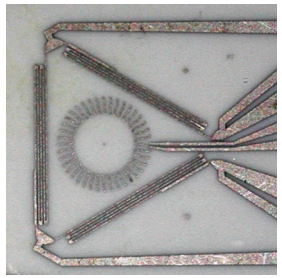




High Temperature Caustic Flow Sensors



Fast, In-Core Thin Film Thermocouple



Embedded Multifunctional Gauges containment deformation and heat flux monitoring

Summary

- NASA GRC is leveraging expertise in thin films and high temperature materials to measure hot gas and surface temperature, heat flux and strain
- Thin film sensors using thermocouples and resistive elements have been designed, fabricated, and demonstrated at GRC for aerospace applications exceeding 900°C
- Thin film sensors of 1 μm or less are attractive for FSP applications because they can be incorporated onto component surfaces with minimal modifications
- Physical sensors fabricated with thin films could result a significant savings in space and weight with improved reliability for monitoring the long-term operation of FSP systems