ADVANCED DATA LOGGING ELECTRONICS FOR HIGH PRESSURE AND TEMPERATURE SUBSURFACE ENVIRONMENTS

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Introduction

Problem

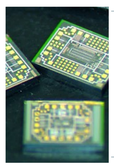
- **Instruments in subsurface environments can encounter temperatures and pressures over 400°C and 150 bar**
- **Enhanced geothermal wells can be up to 3km deep, consisting of temperatures and pressures over 300°C and 150 bar. New wells will have to go deeper and hotter.**

Solution

- **Silicon Carbide Integrated Circuits provide the ability to operate at high temperatures (300 – 600 °C) due to the material properties of SiC– such as a low intrinsic carrier concentration, a large band gap, and a high thermal conductivity.**

Methods

A data acquisition platform that begins with high-temperature wireline logging (WL). Data acquisition and power (tan blocks) can be combined with data processing and advanced acquisition platforms (blue blocks) to enable in-situ analysis.

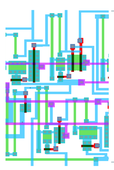


Evaluation and Characterization of Existing SiC Devices

- **Characterize available SiC devices - in both HiTSiC® CMOS (Raytheon) and JFET-R (NASA Glenn Research Center) – for high temperature and pressure.**

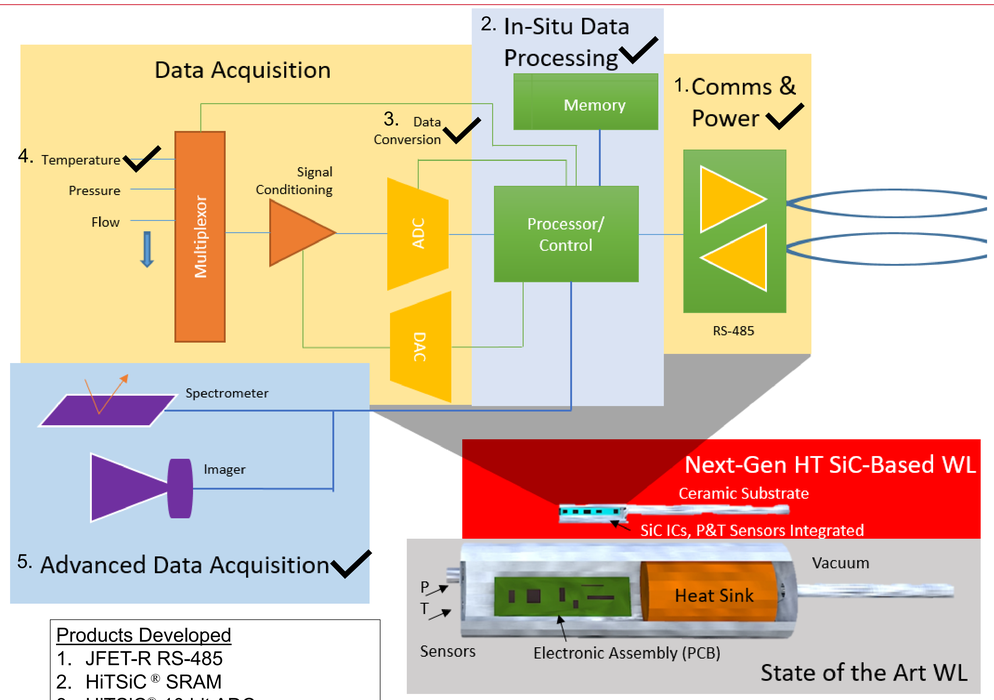
Sensor Development for High Temperature Environments

- **Investigate aerosol jet printing as a manufacturing technique for platinum-based resistors, or RTDs.**



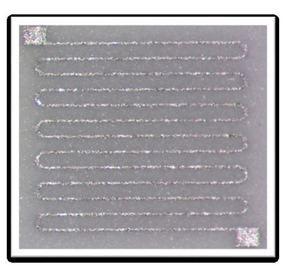
Analog Electronic Design

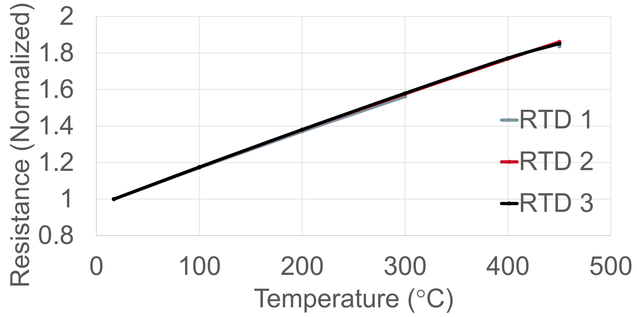
- **Design an optimized ADC in HiTSiC® and RS-485 in JFET-R, and verify performance using parasitic extracted simulations.**



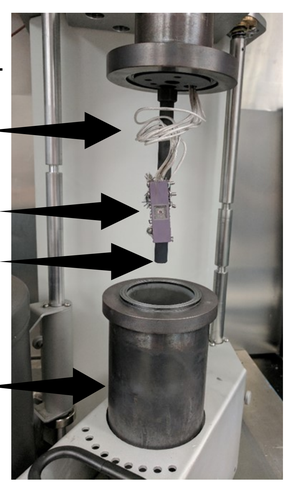
Products Developed
1. JFET-R RS-485
2. HiTSiC® SRAM
3. HiTSiC® 10 bit ADC
4. Integrated RTD Temperature Sensor
5. HiTSiC® UV Imager

Aerosol Jet Printed Platinum Temperature Sensor (over Temperature)



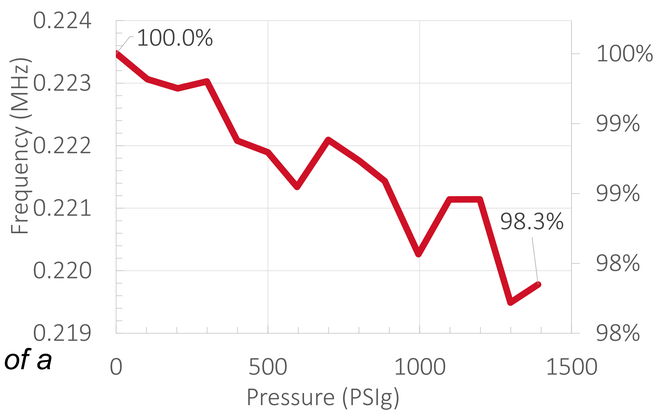


Results

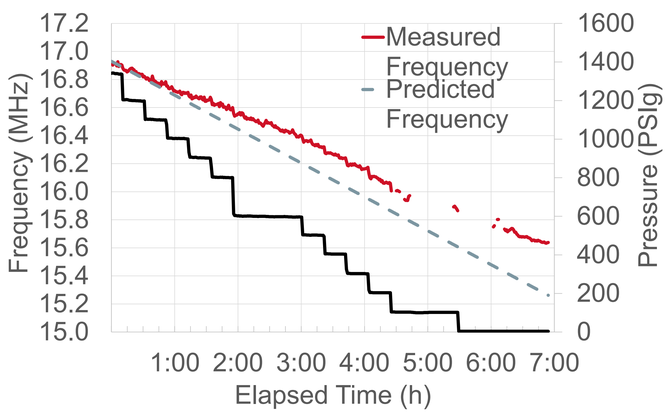


High temperature and pressure testing of a SiC ring oscillator (Courtesy Arkansas Center for Space and Planetary Science).

SiC JFET-R Ring Oscillator Frequency vs Pressure at 475 °C



SiC HiTSiC® Ring Oscillator Frequency vs Pressure at 475 °C



Summary

- **A high temperature high pressure data acquisition chipset provides a clear capability for understanding subsurface resources.**
- **When this chipset is combined with other SiC technology real-time analysis and autonomous acquisition of enhanced geothermal wells becomes a reality.**
- **SiC HiTSiC® and JFET-R Ring Oscillators were tested over temperature and pressure.**
- **An optimized ADC, UV Imager, and SRAM have been designed in HiTSiC®, an new ADC was designed in HiTSiC and an RS-485 was designed in JFET-R. Platinum RTD temperature sensors were investigated using aerosol jet printing.**

Analog Electronic Design

- RS-485 in JFET-R – designed awaiting arrival
- 10 bit ADC in HiTSiC® – designed
- UV Imager in HiTSiC® – ready for evaluation (NASA)

SiC RS-485 Maximum Data Rate (kbaud) Simulation

	25°C			500°C		
VDD	R0	R15	R30	R0	R15	R30
±12	12.5	6.3				
±14	25.0	25.0		6.3	6.3	
±16	25.0	25.0		12.5	12.5	
±18	25.0	50.0	25.0	12.5	12.5	6.3
±20	25.0	25.0	25.0	12.5	12.5	12.5
±25	25.0	25.0	50.0	6.3	6.3	25.0
±30	12.5	25.0	50.0	6.3	6.3	12.5

R# represents the radius from the center of a wafer in mm.

Conclusions

- **In SiC semiconductors at high temperature/pressure, the temperature effects dominate pressure effects.**
- **The RTD printed temperature sensors can be printed on alumina substrates. With optimized cure time, the resistance observed is extremely repeatable.**
- **Designed CMOS 16 channel16 bit ADC can achieve up to samples/second at 470°C**
- **JFET RS-485 can achieve up to 25 kbaud transmission at 500°C**

Future Work

- **Evaluate chipset blocks**
- **Design and fabricate pressure and flow sensor modules**

SiC Wafer