COPYRIGHT NOTICE

www.bitsworkshop.org

Applications for Embedded Micro Heaters in Printed Circuit Boards and MEMS Sensors

Bruce P Mahler
Ohmega Technologies, Inc.

BiTS Workshop
March 4 - 7, 2018

Agenda

- Trends in micro heater applications
- Micro heater use in micro Total Analysis Systems (µTAS's)
- Lab-On-Chip (LOC) versus Lab-On-PCB (LOP)
- Micro heater use in PCB substrate of other MEMS sensors
- Micro heater test data
- Illustrate two application examples using microheaters

Application Trends for Micro Heaters

- Microfluidic biological sensors
- In-Vitro diagnostic analysis
- DNA and RNA analysis
- Dissolved organic matter analysis in seawater
- Micro reactors for pharmaceutical development
- Portable point of care, rapid blood screening for contagions/diseases
- Gas sensing air quality

Micro Total Analysis Systems

Growing demand for commercialization of micro Total Analysis Systems (μTAS's) is requiring designers to reconsider the printed circuit board. Many Lab-On-Chip (LOC) devices have been successfully demonstrated but because of cost restrictions have failed to proliferate. Lab-On-PCB (LOP) is being recognized as a tangible solution.

Lab-On-Chip (LOC) Devices

Produced by semiconductor processes on silicon or glass.

Advantages

- Semiconductor fabrication techniques
- Highly integrated devices possible
- Biocompatible
- Very small footprint

Disadvantages

- Expensive material and processing equipment
- Footprint limitations make point of care applications difficult
- Better suited for laboratory environments

Lab-On-PCB (LOP) Devices

Lab-On-PCB devices include processors, MEMS sensors / microfluidic devices and require microheaters.

Nickel Phosphorus (NiP) thin-film resistors as microheaters:

- Eliminate discrete chip resistors
- Allow custom micro heater footprints through subtractive print/etch
- Easily tunable resistance for power/heat requirements
- Localize heat to very small areas
- Provide reliable, long term use

Lab-On-PCB (LOP) Devices

Produced using standard Printed Circuit Board processes.

Advantages

- Global infrastructure using standardized processes and materials
- Quick prototyping and ramp to scale
- Heaters embedded in the printed circuit board
- Lower cost production

Disadvantages

- May require assembly of additional components

NiP Thin-Film Resistors as Heaters in PCBs

- Aerospace & Defense
  - SAL (semi-active laser) activation guided munitions
  - XRF Spectrometer & Control board (Mars Beagle 2 lander)
  - Satellite solar array deployment mechanism
- Biomedical Electronics
  - Bioassay
  - Drug vaporization for subcutaneous injections
  - Heat therapy for dry eye
- PCB Temperature Control
- IC Testing/Burn-In

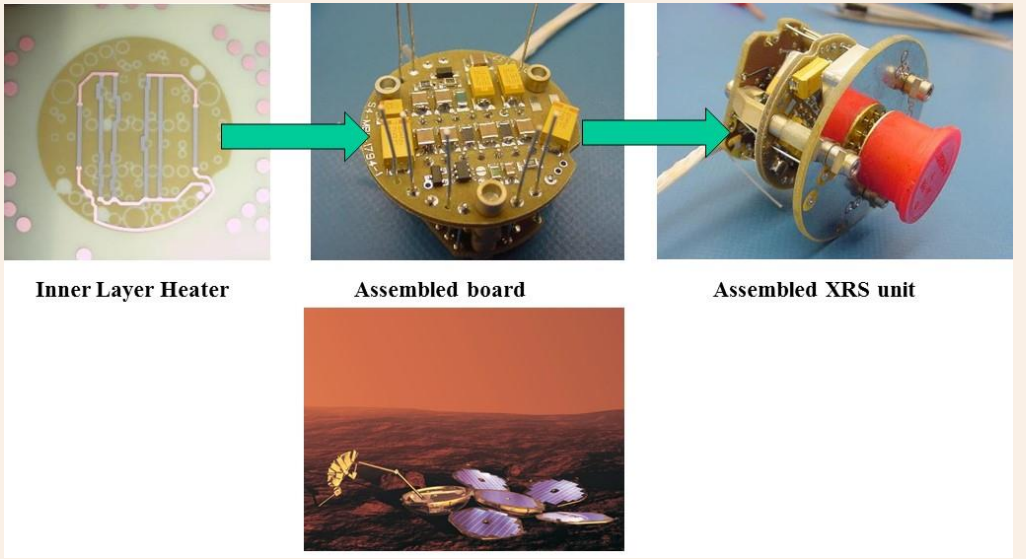
NiP Thin-Film Resistors as Heaters in PCBs

Advantages of using NiP thin-film resistors are:

- Improved reliability (removal of solder joints)
- Fewer parts to assemble
- Custom resistor footprints
- Fast temperature rise times
- Low RTC characteristic <50 ppm/C (-65C to +125C)
- Stable values at high ambient temperatures (150C+)

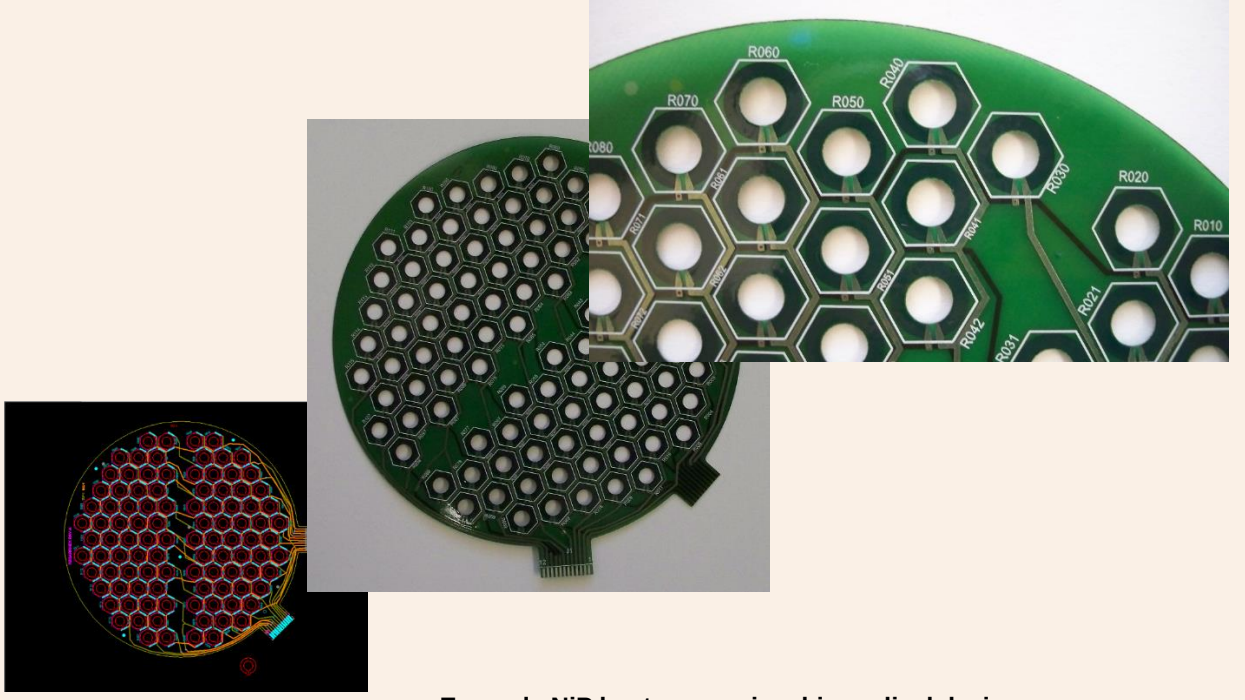
NiP Thin-Film Resistors as Heaters in PCBs

- Application shows a heater used to bring the X-Ray Spectrometer (XRS) biasing and pre-amplification electronics to -50 degrees Celsius in the Mars Beagle 2 Lander.



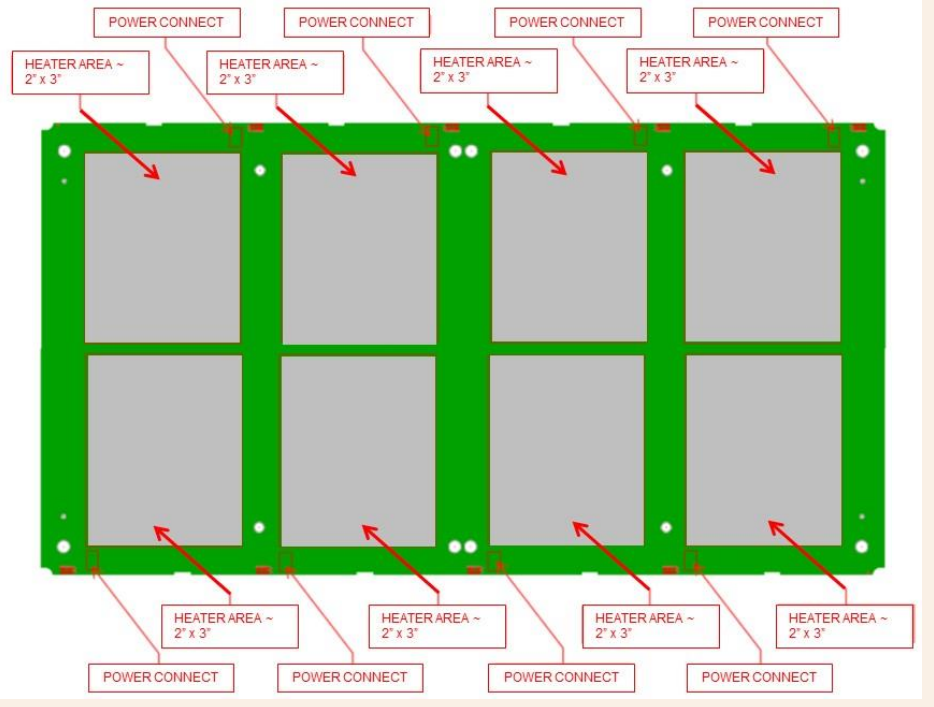
Images Courtesy of the University of Leicester Space Research Centre and the Beagle2 Consortium

NiP Thin-Film Resistors as Heaters in PCBs



Example NiP heater array in a biomedical device

NiP Thin-Film Resistors as Heaters in PCBs



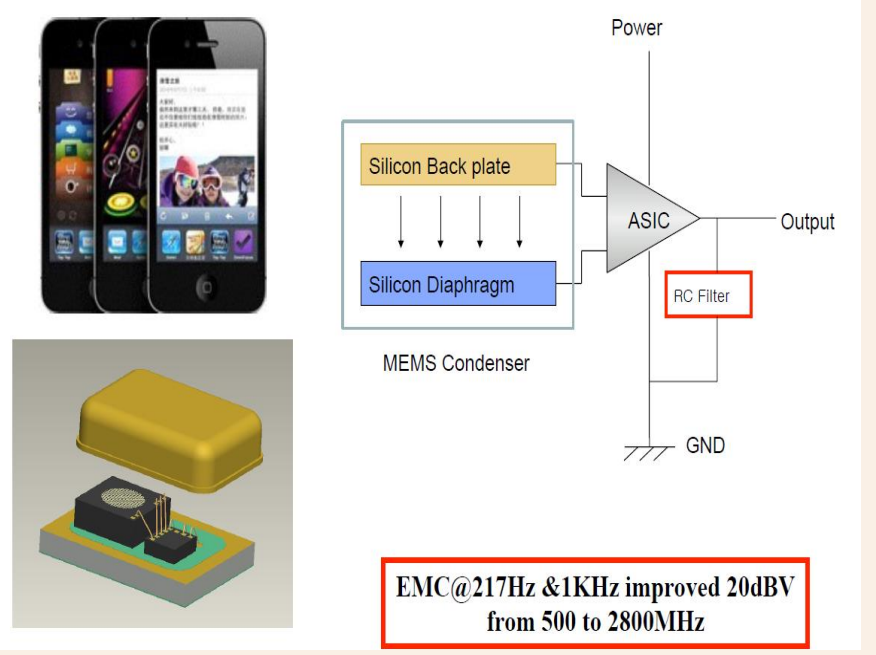
Example 10 ohm/sq embedded heater array for IC Burn-In testing at 65C

NiP Thin-Film Resistors in High Volume Application

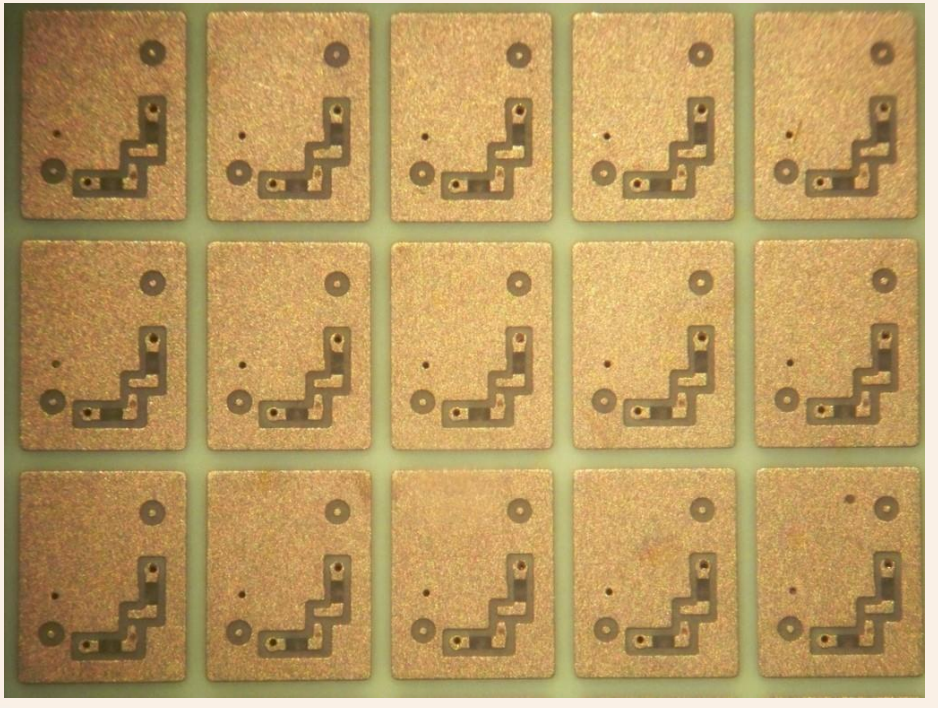
NiP thin-film resistors have been extensively used for many years in MEMs Microphone PCBs. These devices are deployed in headsets, cellular phones and various voice controlled systems. Advantages of using NiP thin-film resistors are:

- Improved reliability (removal of solder joints)
- Fewer parts to assemble
- Small resistor footprints
- Less board area for components allowing for smaller and thinner PCBs
- Improved electrical performance (lower EMI)

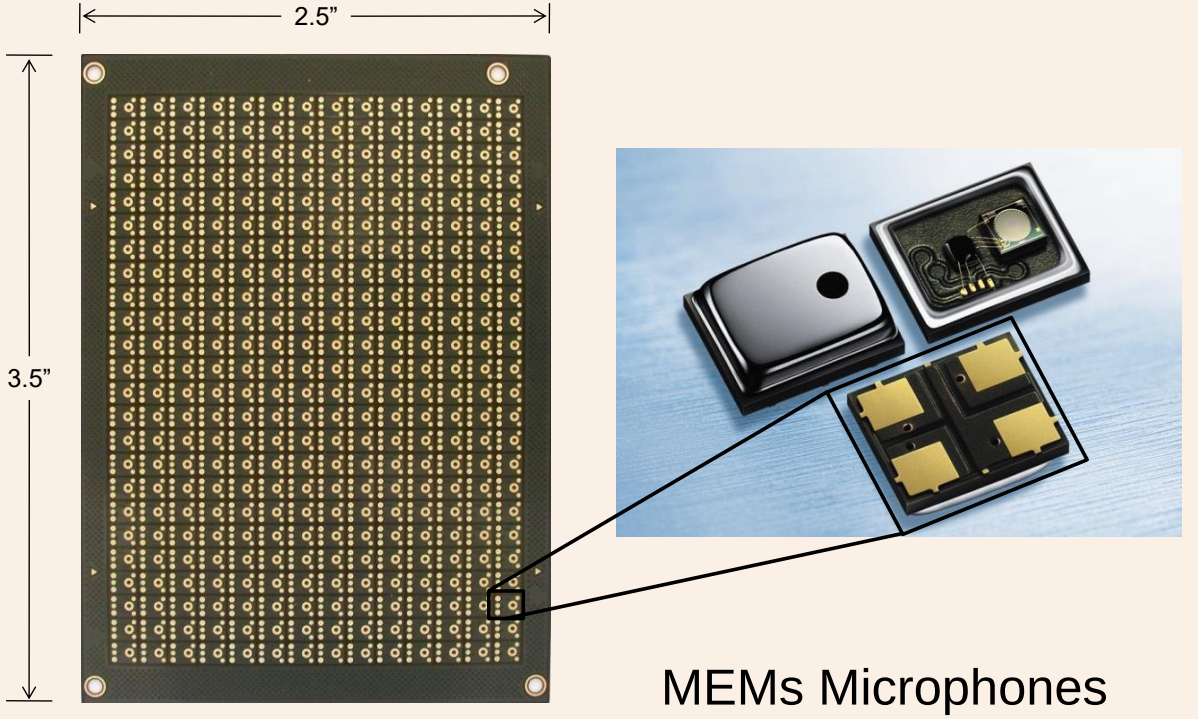
NiP Thin-Film Resistors in MEMs Microphone Sensor



NiP Thin-Film Resistors in MEMs Microphone Sensor



NiP Thin-Film Resistors in MEMs Microphone Sensor

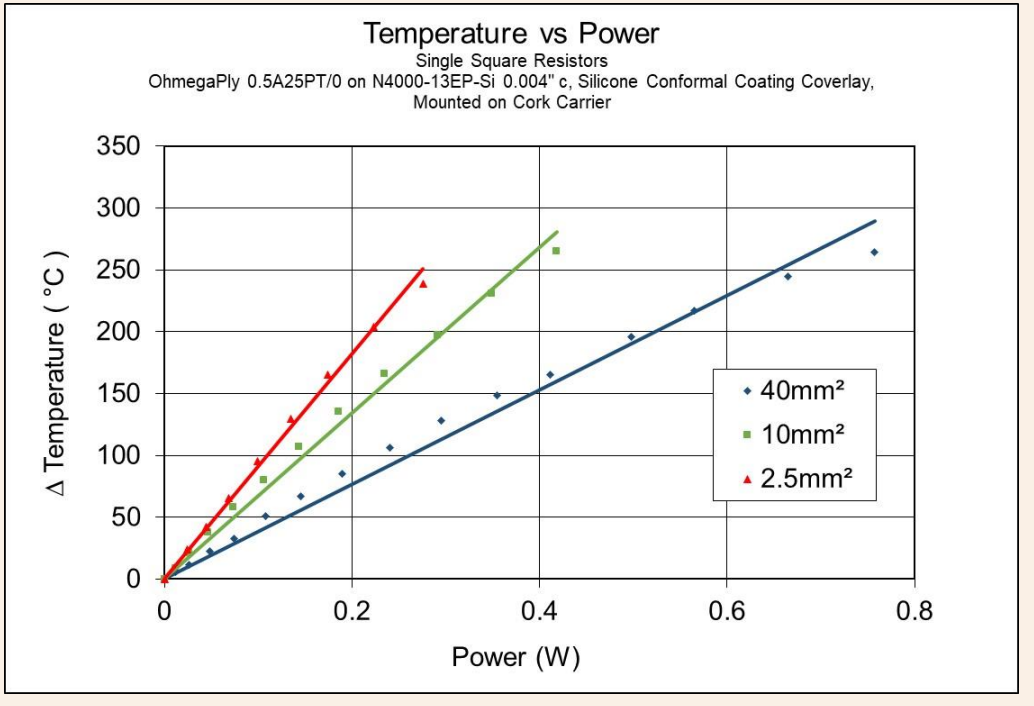


MEMs Microphones

NiP Thin-Film Micro heater Testing

- Review measurements on relatively larger NiP 'macro' heaters
- Temperature rise vs. power on NiP micro heater
- Temperature vs. rise time on NiP micro heater
- Temperature rise vs. NiP sheet resistivity

Temperature Rise vs Power for Larger NiP Thin-Film Resistors (Macroheaters)

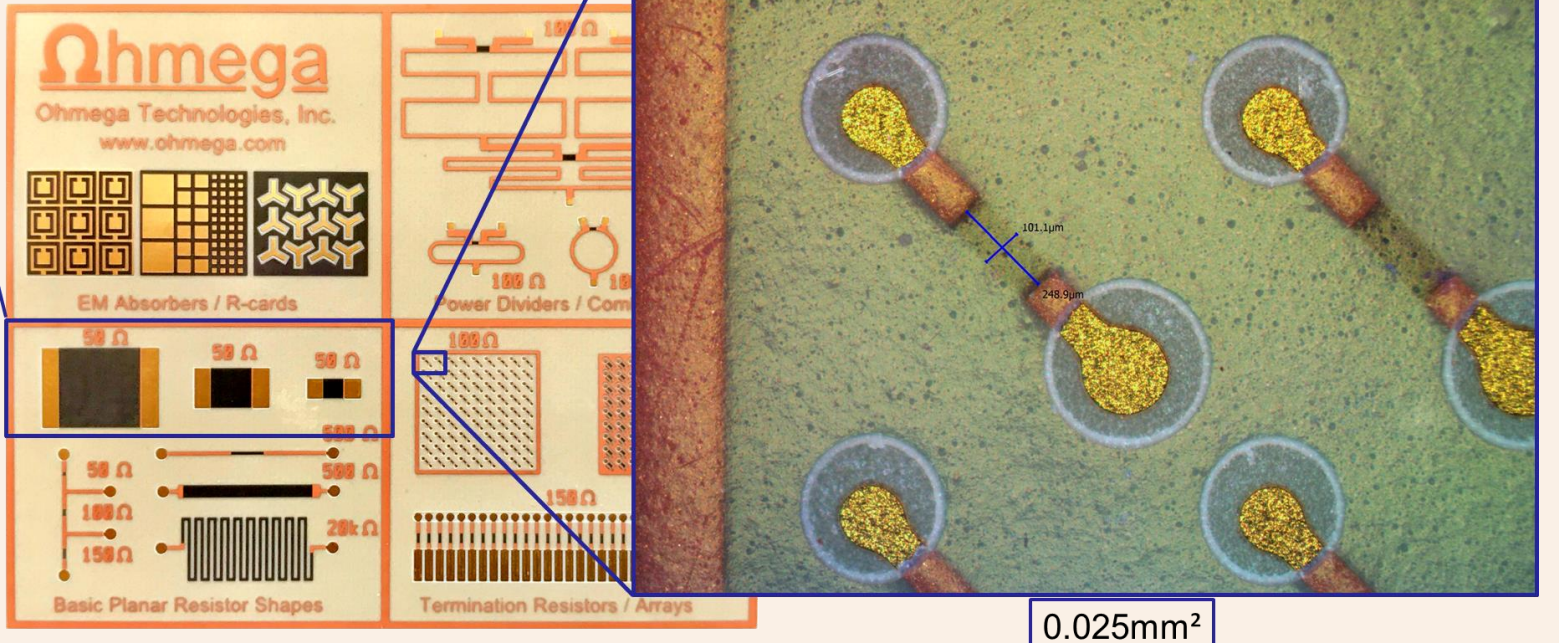


PCB NiP Thin-Film Micro heater Definition

- For our discussion we define microheaters as resistive elements with an area less than 0.25 mm².
- For this particular study, the heater elements were constrained to a rectangular shape with an area of 0.025 mm² (0.10 mm x 0.25 mm).

Macro Heaters

40mm², 10mm², 2.5mm²



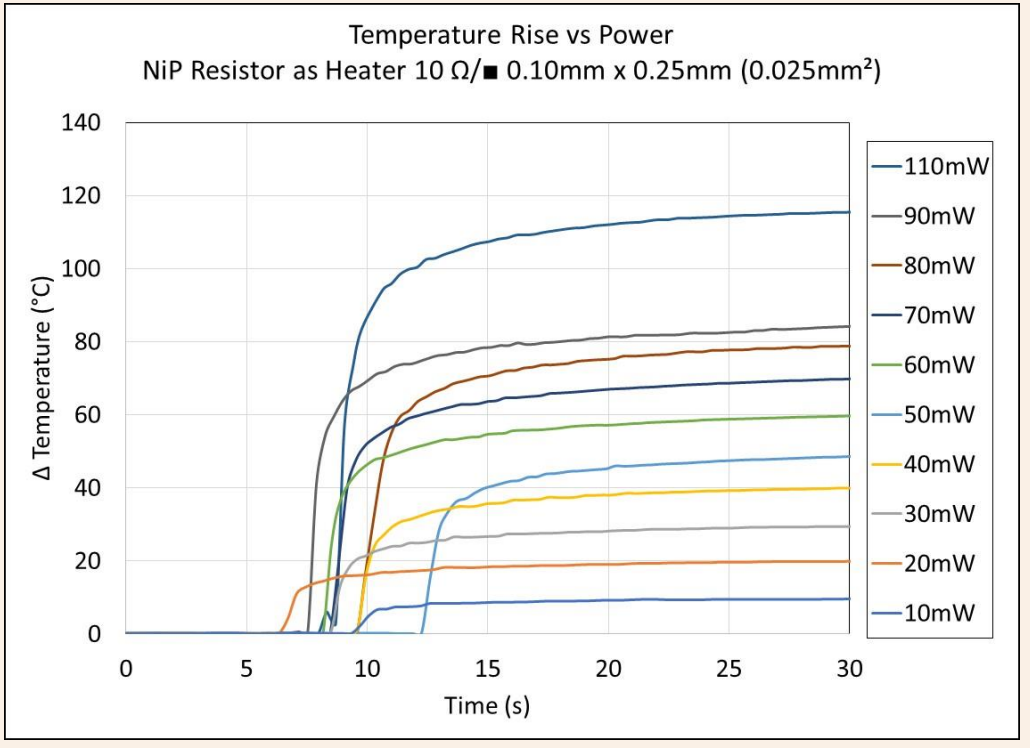
0.025mm²

Micro Heaters

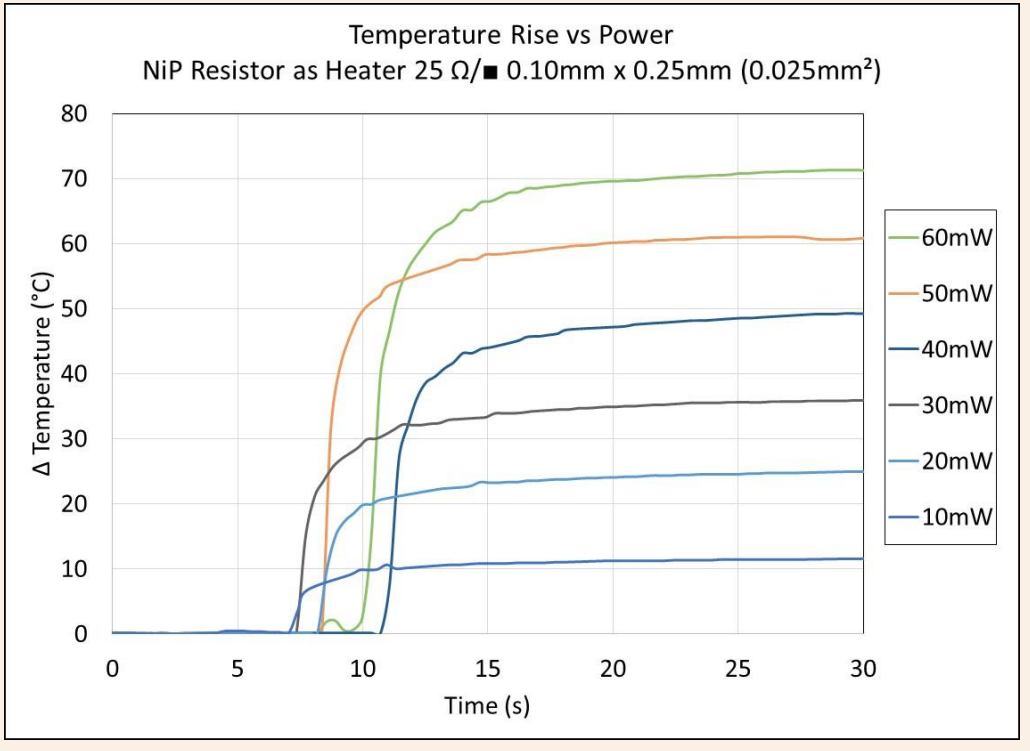
Temperature Rise versus Power

- The tests were conducted comparing temperature versus power input for various NiP sheet resistivities.
- NiP resistor as heaters were tested at a fixed size of 0.025 mm² (0.10 mm x 0.25 mm).
- The construction of the test boards were:
  - Isola 370HR, 0.004” core
  - No backside cladding
  - Clear solder mask

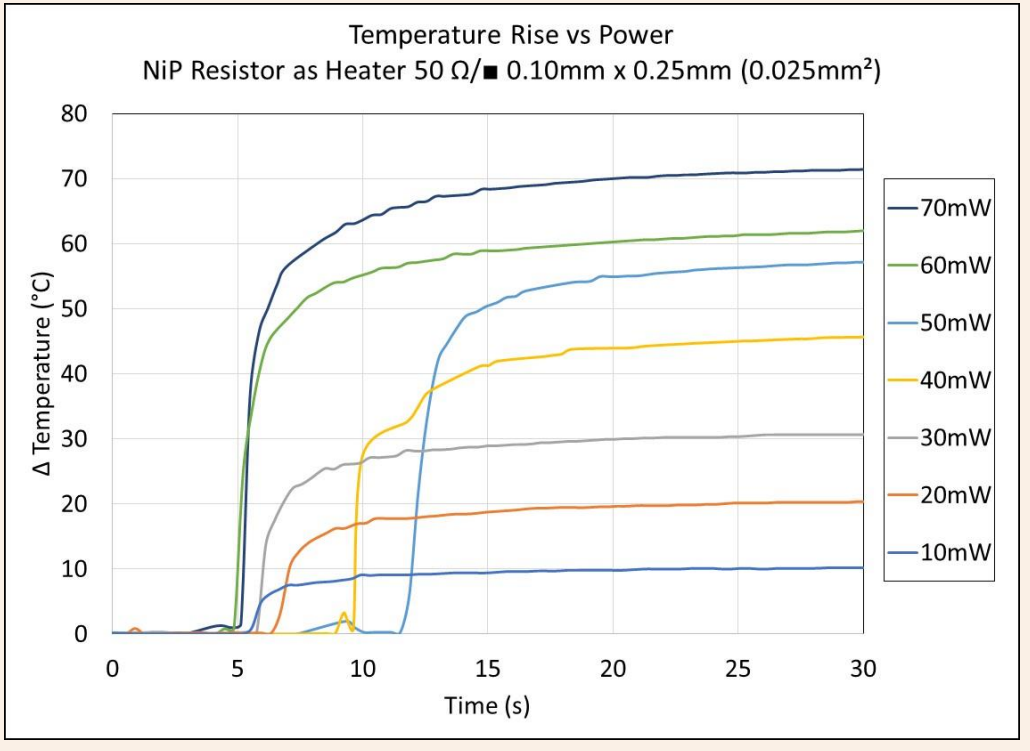
Temperature vs Power Data



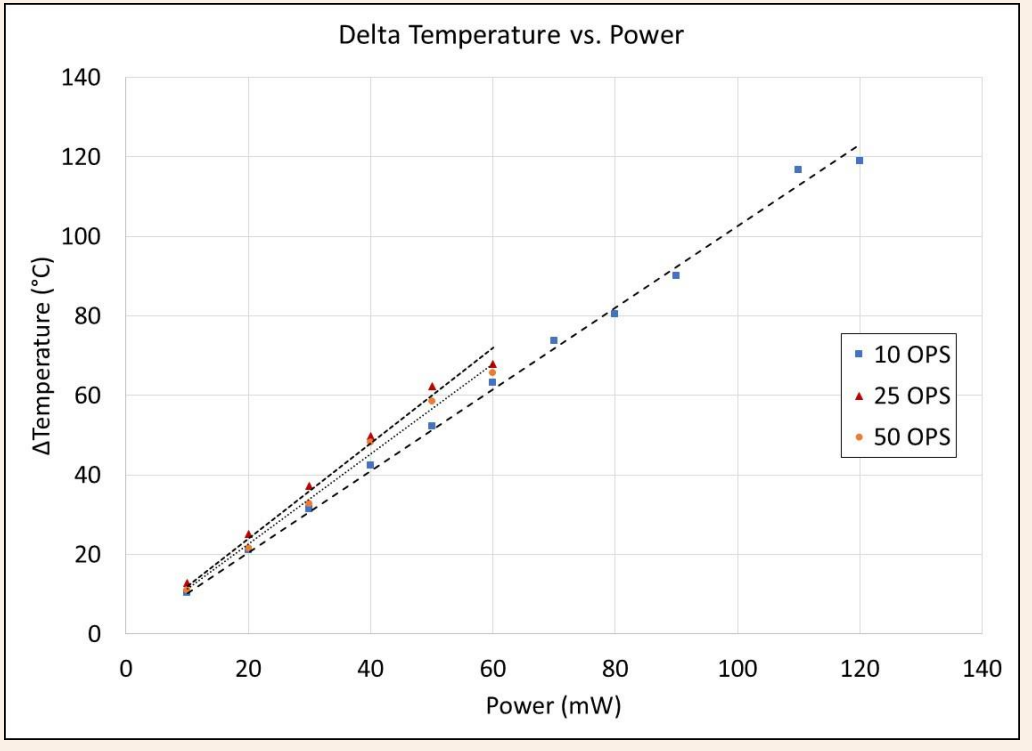
Temperature vs Power Data



Temperature vs Power Data



Temperature vs Power Data Summary Chart



Concept Application Illustration

NiP resistor as heater illustration

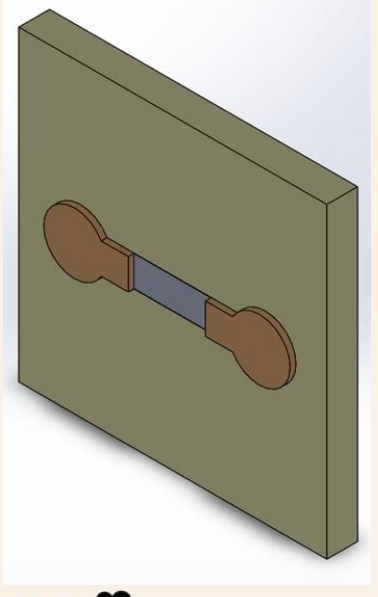


Illustration showing NiP resistor/heater on inner layer. Surface mount footprint with thermal conduit pad in center.

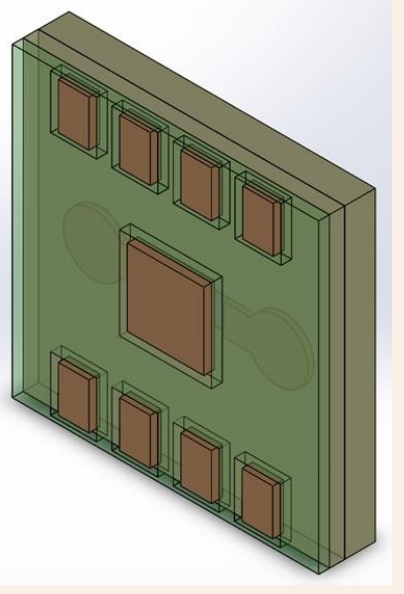
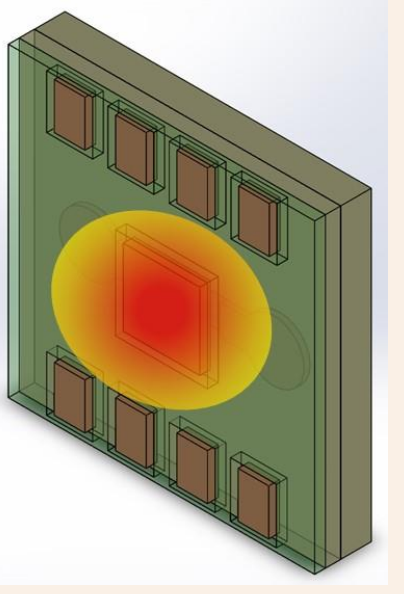


Illustration depicting heat flow on surface layer thermal pad from underlying NiP resistor/heater.



Concept Application Illustration

NiP resistor as heater illustration

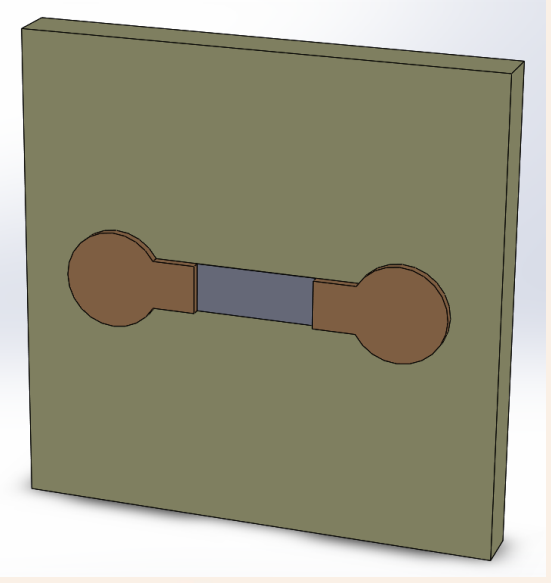


Illustration showing NiP resistor/heater on inner layer. Cavity with various channels.

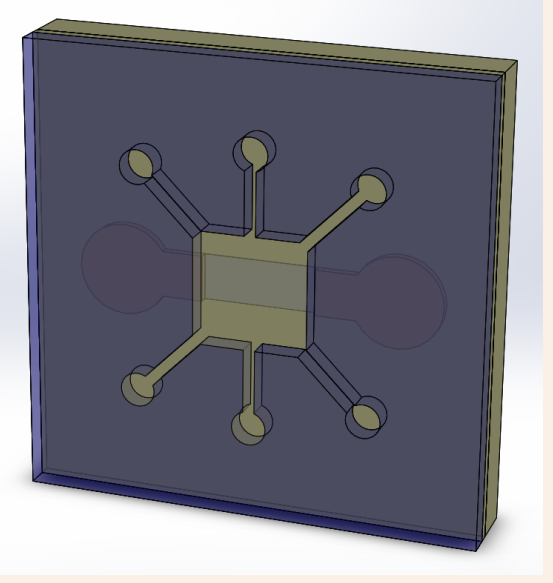
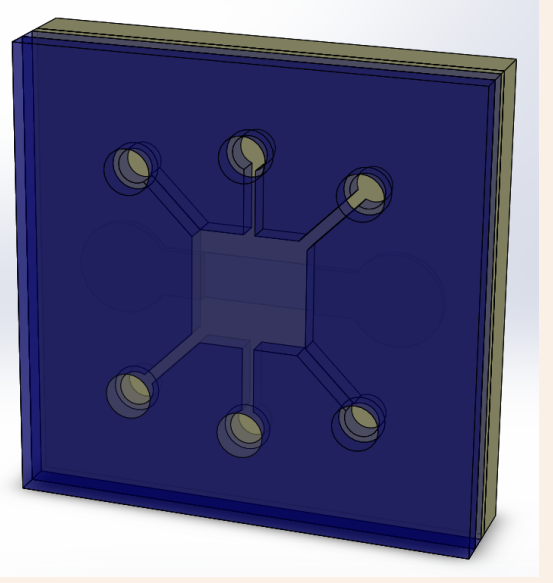


Illustration depicting enclosed cavity in PCB with various channel access ports.



Study Summary

- NiP microheaters demonstrated good correlation between temperature rise and input power.
- The NiP microheaters required relatively low power and fast rise times to achieve maximum temperature.
- The temperature of the micro heater was limited by the maximum operating temperature of the substrate and protective conformal coating over the resistors. Higher temperature resistant substrates (for instance, polyimide) and copper heatsink planes near the resistive elements will allow for higher power and temperatures.
- Applications using NiP as microheaters are now under development/pre-production in both MEMs PCBs and Lab-on-PCBs with excellent initial results.