Micro Bolometer

Dr. Lynn Fuller

Webpage: http://people.rit.edu/lffeee
Electrical and Microelectronic Engineering
Rochester Institute of Technology
82 Lomb Memorial Drive
Rochester, NY 14623-5604
Tel (585) 475-2035
Email: Lynn.Fuller@rit.edu
Department webpage: http://www.rit.edu/kgcoe/eme/MicroEoverview

11-6-2014 MicroBolometer.ppt

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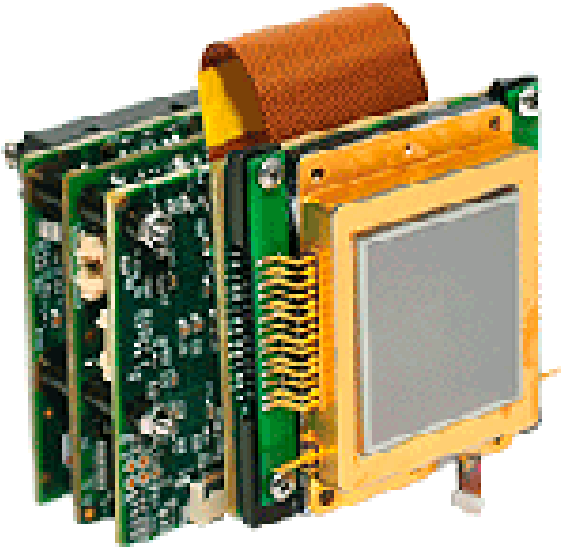
OUTLINE

Introduction
Manufactures & Applications
Theory – Black Body Radiation
Adsorption vs Wavelength
Resistors
Readout Amplifier
Pixel Array
Fabrication Process
Test Results
Packaging
Commercial Devices
Applications
References
Homework



INTRODUCTION

A Bolometer is an infrared detector that works on a change in resistance resulting from the absorption of radiant infrared energy with wavelengths between 5 and 15µm. These sensors operate at room temperature and do not require cooling. At these wavelengths electron-hole pair generation is not the mechanism for resistance change since the photon energy is not higher than the material band gap. The infrared photons can be absorbed by the free carriers (electrons or holes) increasing their energy which upon relaxation increases the temperature of the material slightly. The sensor should be low mass, able to absorb infrared energy and be thermally isolated from surrounding materials. Materials such as amorphous silicon and vanadium oxide have been used for the sensor material. The resistors themselves should have a large temperature coefficient of resistance (TCR) and low sheet resistance (for low noise).

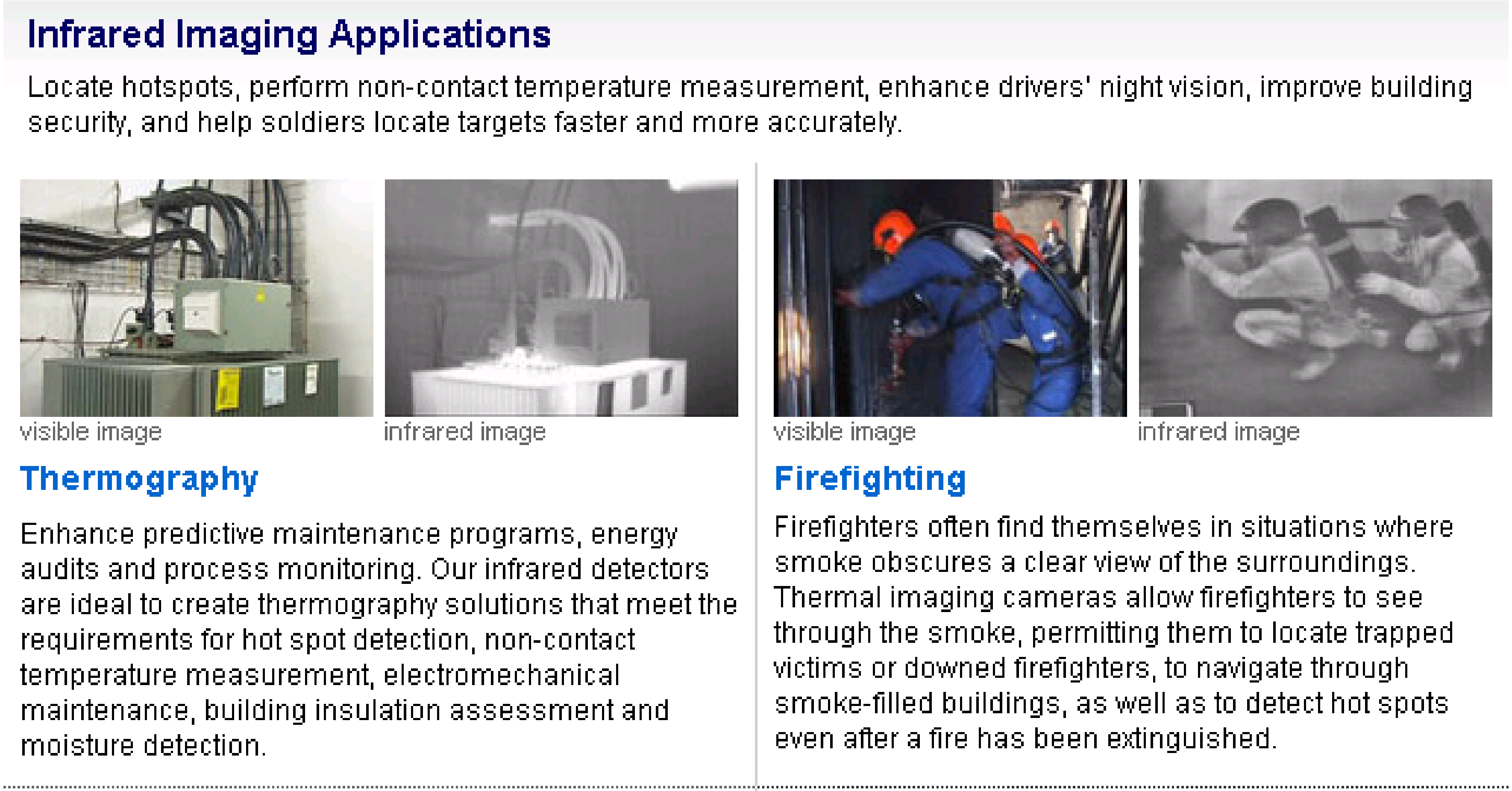
INTRODUCTION

MANUFACTURERS

Fluke Corporation
BAE Systems
Raytheon
L-3 Communications Infrared Products
DRS Technologies
GUIDR
FLIR Systems
Opgal Optronics Ltd
Vumii Imaging
InfraredVision Technology Corp.
NEC
Institut National d'Optique
Honeywell
ULIS-IR

The FLIR Systems ThermoVision SENTRY Infrared Imaging System utilizes a 320×240 microbolometer array.

APPLICATIONS



Infrared Imaging Applications

Locate hotspots, perform non-contact temperature measurement, enhance drivers' night vision, improve building security, and help soldiers locate targets faster and more accurately.

visible image

infrared image

Thermography

Enhance predictive maintenance programs, energy audits and process monitoring. Our infrared detectors are ideal to create thermography solutions that meet the requirements for hot spot detection, non-contact temperature measurement, electromechanical maintenance, building insulation assessment and moisture detection.

visible image

infrared image

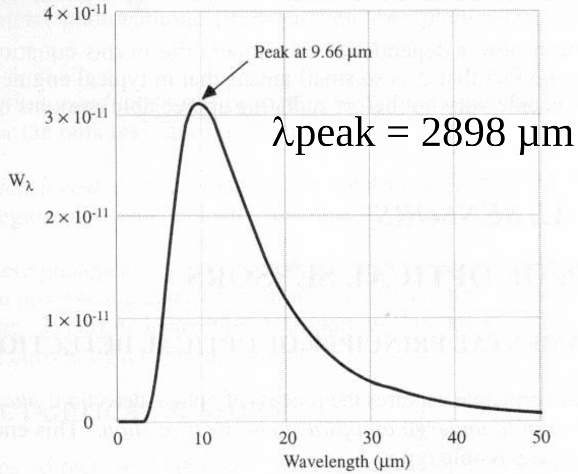
Firefighting

Firefighters often find themselves in situations where smoke obscures a clear view of the surroundings. Thermal imaging cameras allow firefighters to see through the smoke, permitting them to locate trapped victims or downed firefighters, to navigate through smoke-filled buildings, as well as to detect hot spots even after a fire has been extinguished.

BLACK BODY RADIATION

From: Micromachined Transducers, Gregory T.A. Kovacs

From: Solar Cells, Martin A. Green, Prentice Hall



λpeak = 2898 µm / T

Plot of W_λ versus λ (µm) for a 300 K (room temperature) object assuming ε = 1 (human body temperature corresponds to a peak at ≈ 9.4 µm).

$$W_\lambda = \frac{\varepsilon(\lambda)\, 2\pi hc^2}{\lambda^5} \, \frac{1}{\left(e^{\frac{hc}{\lambda kT}} - 1\right)} \quad \text{in W/m}^2$$

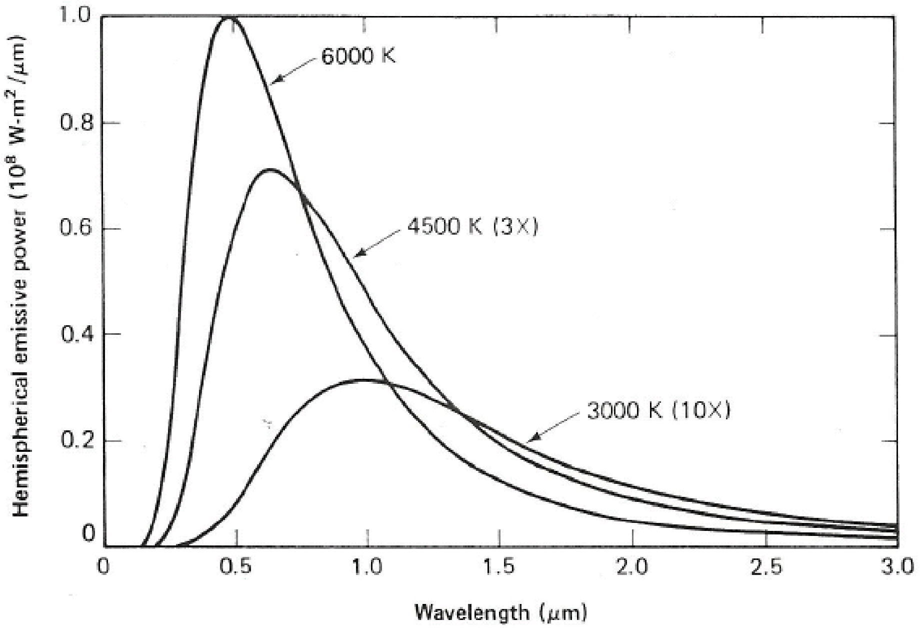


Figure 1.1. Planckian black-body radiation distributions for different black-body temperatures.

Wien’s Displacement Law

λpeak = 2898/T (µm)

h = 6.6262E-34 J s = 4.1361E-15 eV s

$\lambda = c/\nu$ k=1.38e-23 J/K

W_λ = radiant flux

ε(l) = emissivity (dimensionless, ε=1 for black body)

THEORY

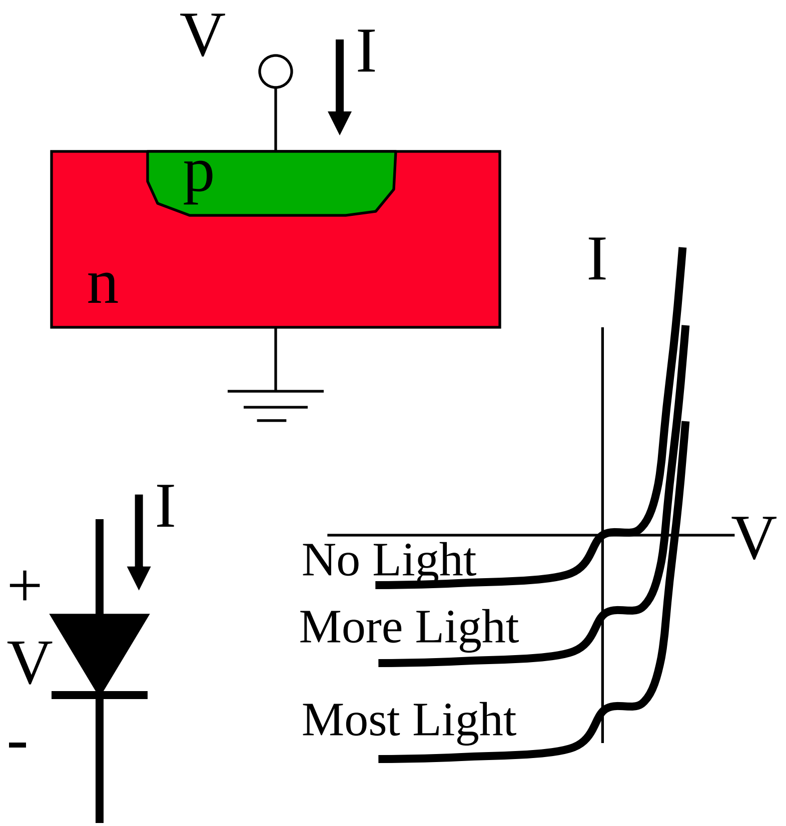
Resistance Change (Responsivity, TCR)

Materials

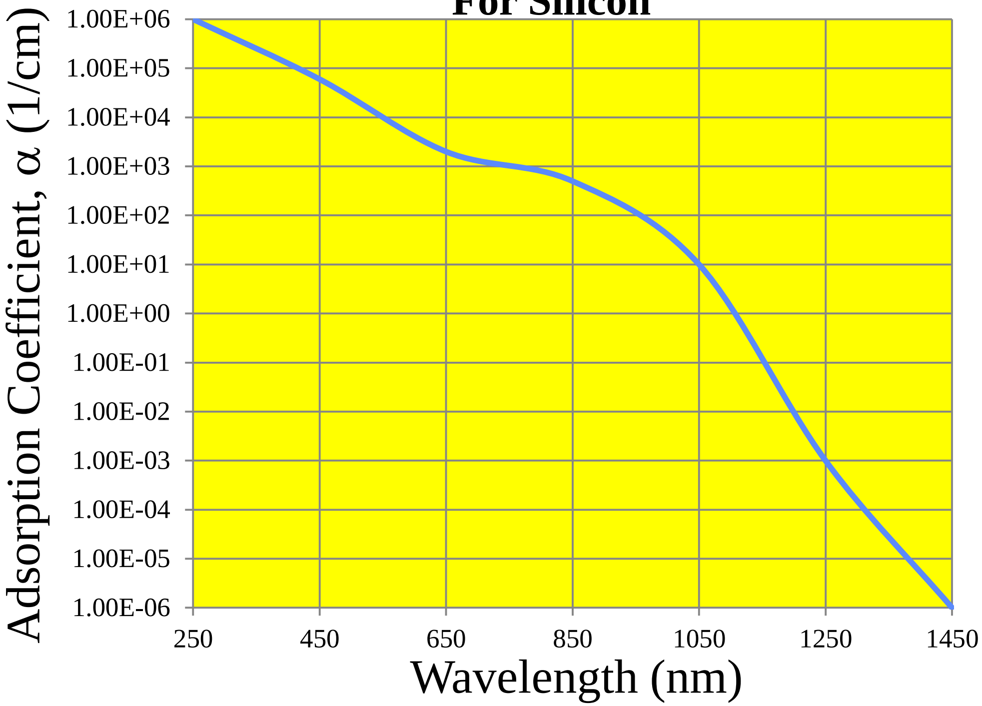
Noise

Active vs Passive

ADSORPTION VERSUS DISTANCE



Adsorption Coefficient vs Wavelength For Silicon



$$\phi(x) = \phi(0) \exp^{-\alpha x}$$

Find % adsorbed for Green light at x=5 µm and Red light at 5 µm

SILICON AND POLYSILICON MATERIALS

Single Crystal Silicon

Adsorption coefficient α at λ = 0.5um is 1E4 /cm

Adsorption coefficient α at λ = 1.4um is 3.2E-8 /cm

Polysilicon

Adsorption coefficient α at λ = 0.5um is 5.074E4 /cm

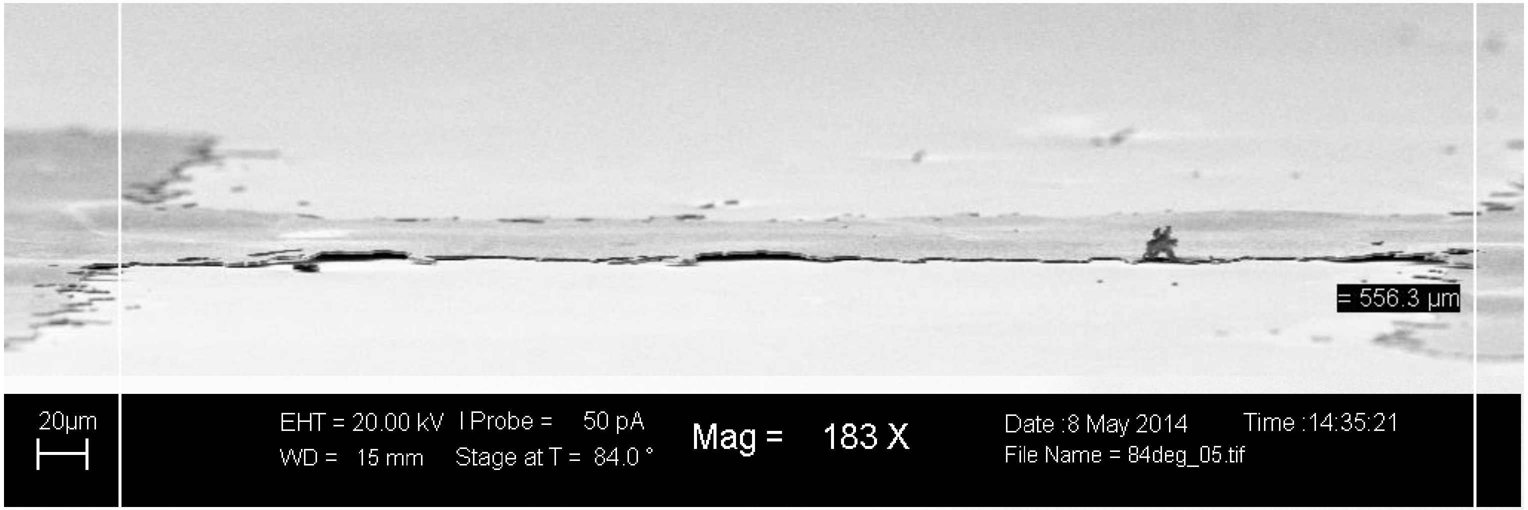
Adsorption coefficient α at λ = 1.2um is 1.0E-2 /cm

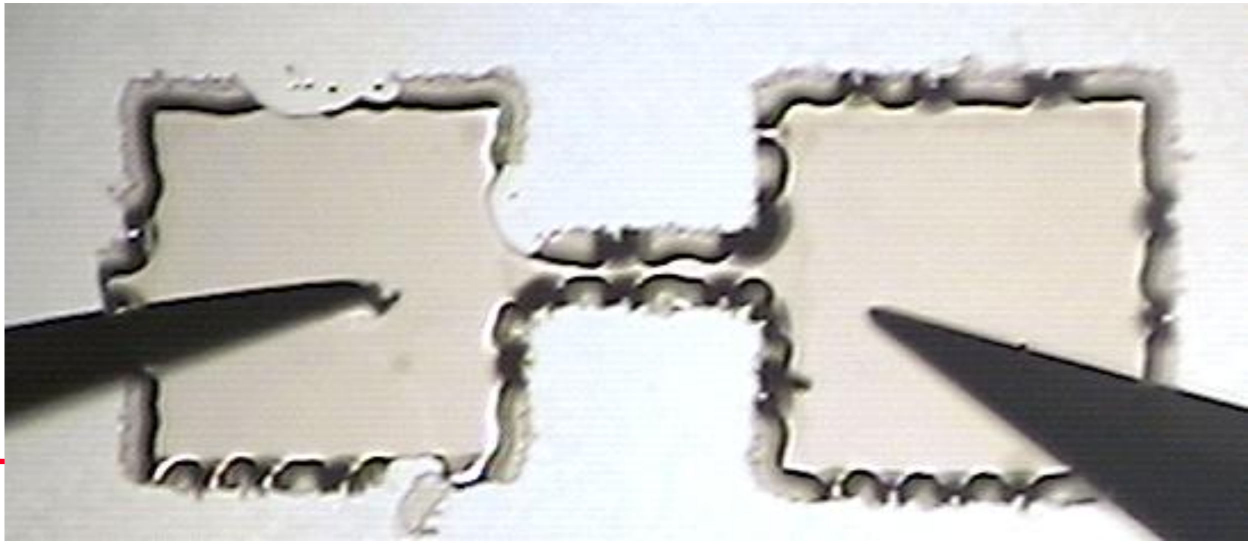
Amorphous Silicon

Adsorption coefficient α at λ = 0.5um is ???E? /cm

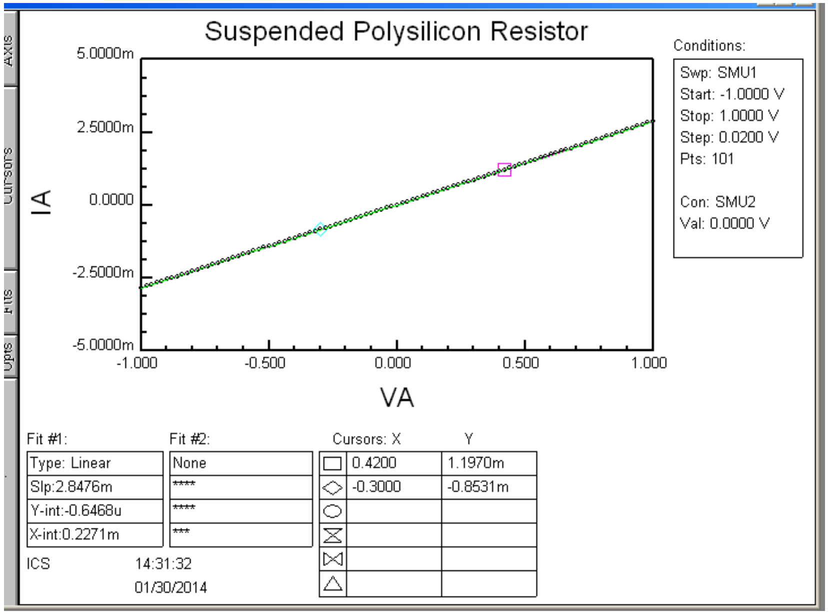
Adsorption coefficient α at λ = 3um is ???E? /cm

SUSPENDED POLYSILICON RESISTOR





SUSPENDED POLYSILICON RESISTOR



Conditions:

Swp: SMU1
Start: -1.0000 V
Stop: 1.0000 V
Step: 0.0200 V
Pts: 101

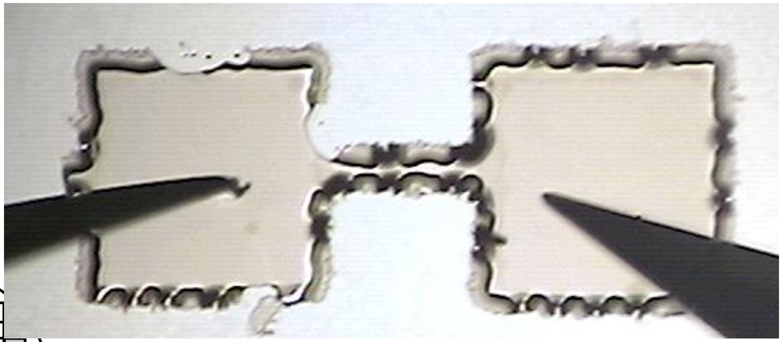
Con: SMU2
Val: 0.0000 V

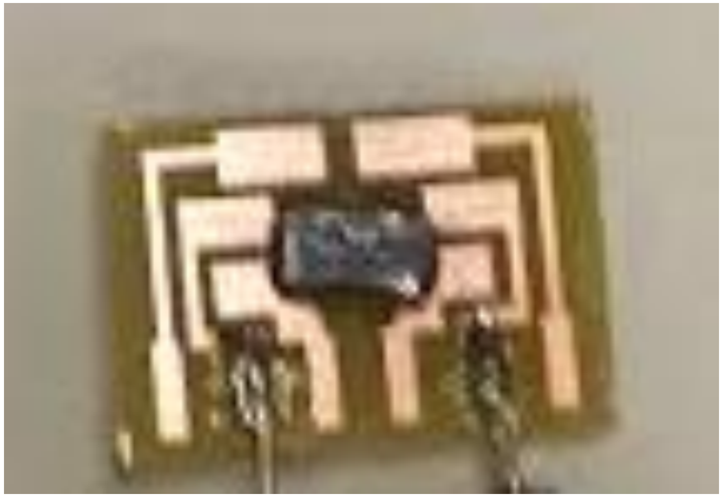
Fit #1:	Fit #2:
Type: Linear	None
Slp:2.8476m	****
Y-int:-0.6468u	****
X-int:0.2271m	***

Cursors:	X	Y
□	0.4200	1.1970m
◇	-0.3000	-0.8531m
○		
⧗		
⋈		
△		

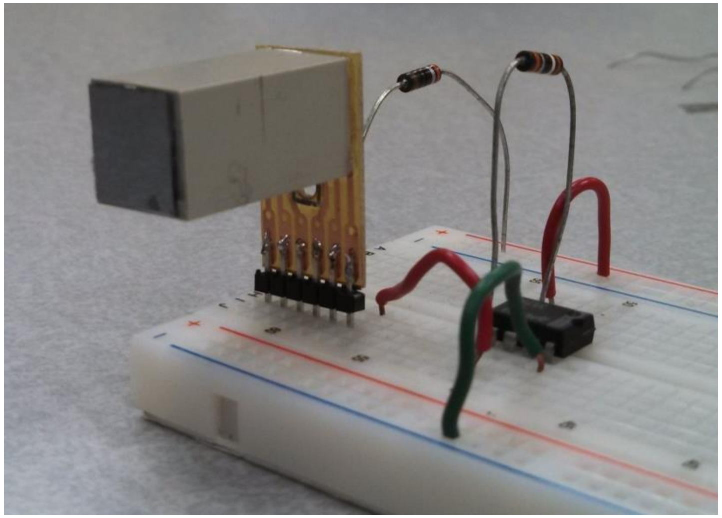
ICS 14:31:32
01/30/2014

Resistor	Resistance
No Heat	267.41 Ω
Heat (No Light)	267.42 Ω
Heat (Uncovered)	267.47 Ω



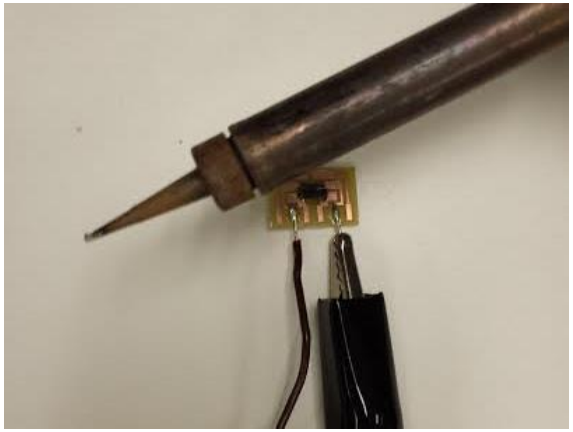


SUSPENDED POLYSILICON RESISTOR

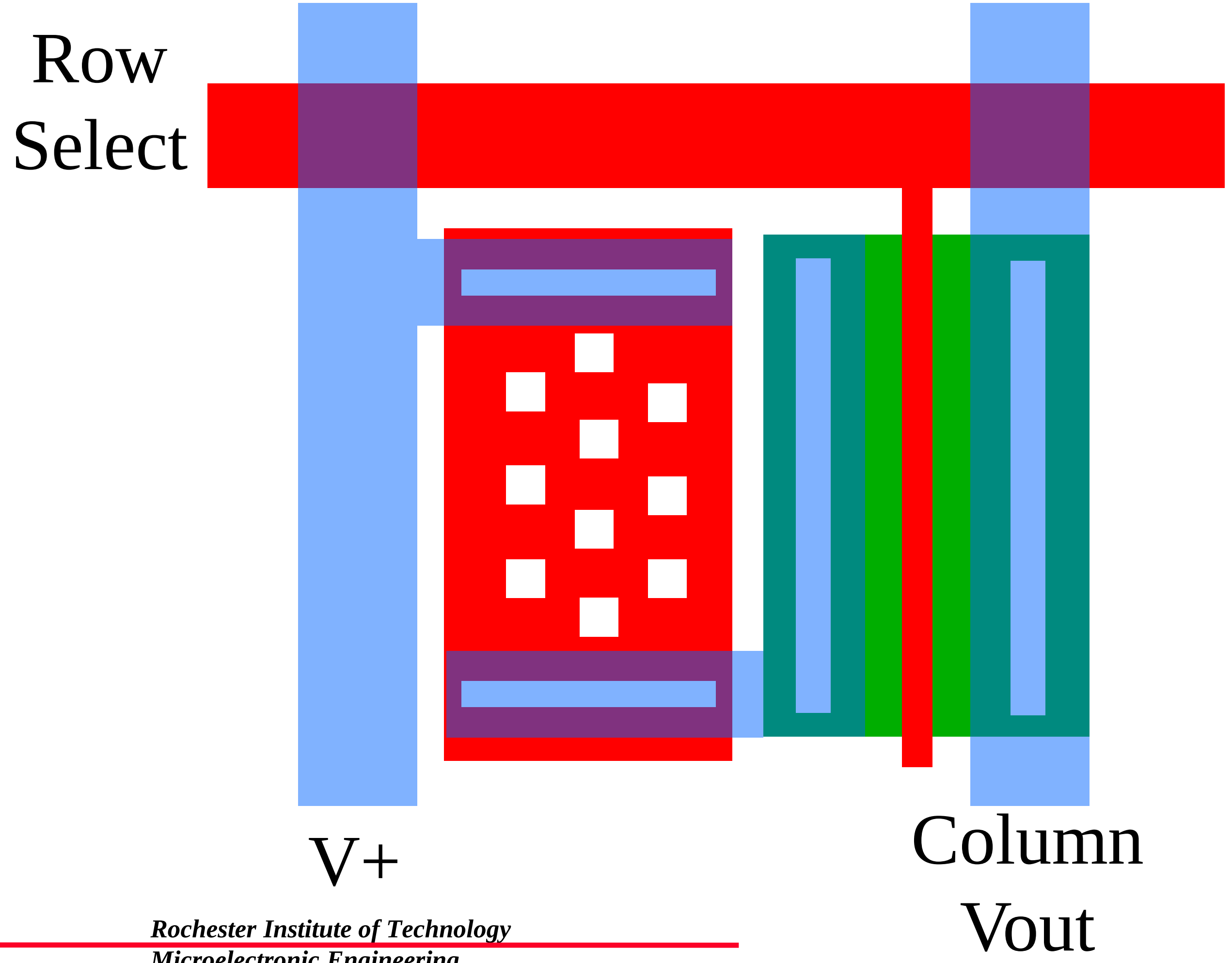


Sensitivity = 10mohms/267ohms/100/°C
= 0.004%/°C

Compared to industry TCR’s of 2.0%/°C



PIXEL LAYOUT

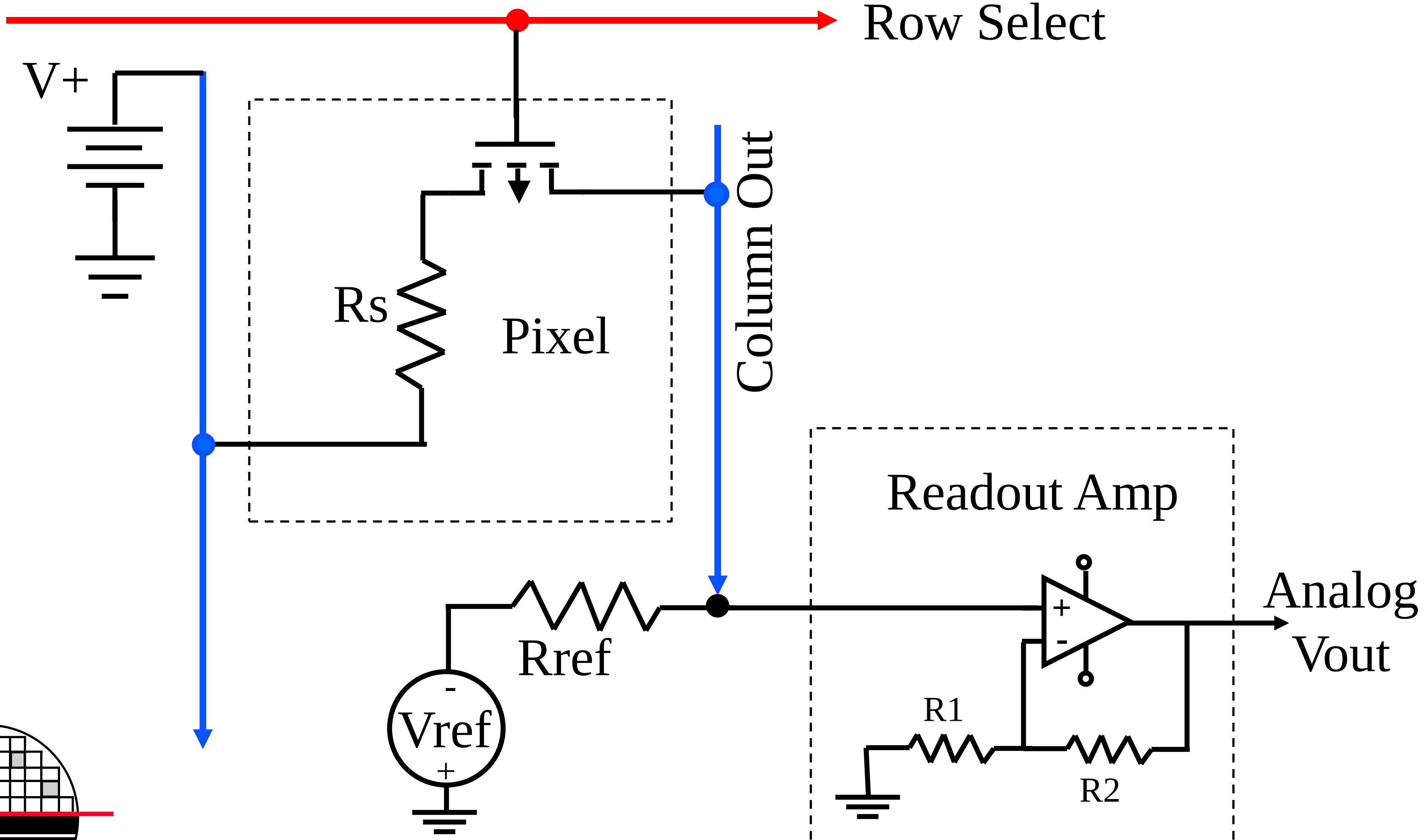


Row Select

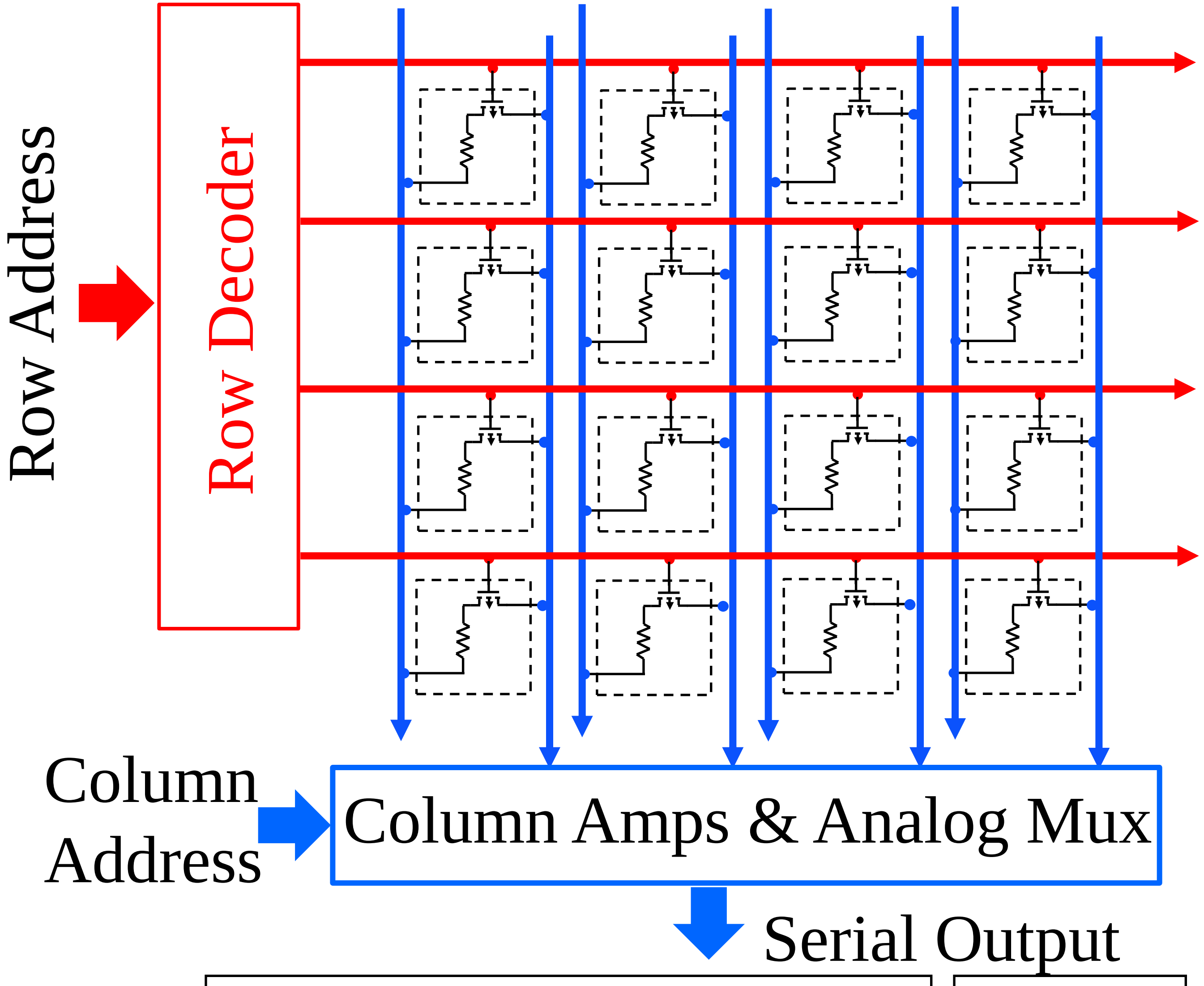
V+

Column Vout

SINGLE PIXEL AND READOUT AMPLIFIER



4x4 PIXEL ARRAY



Row Address

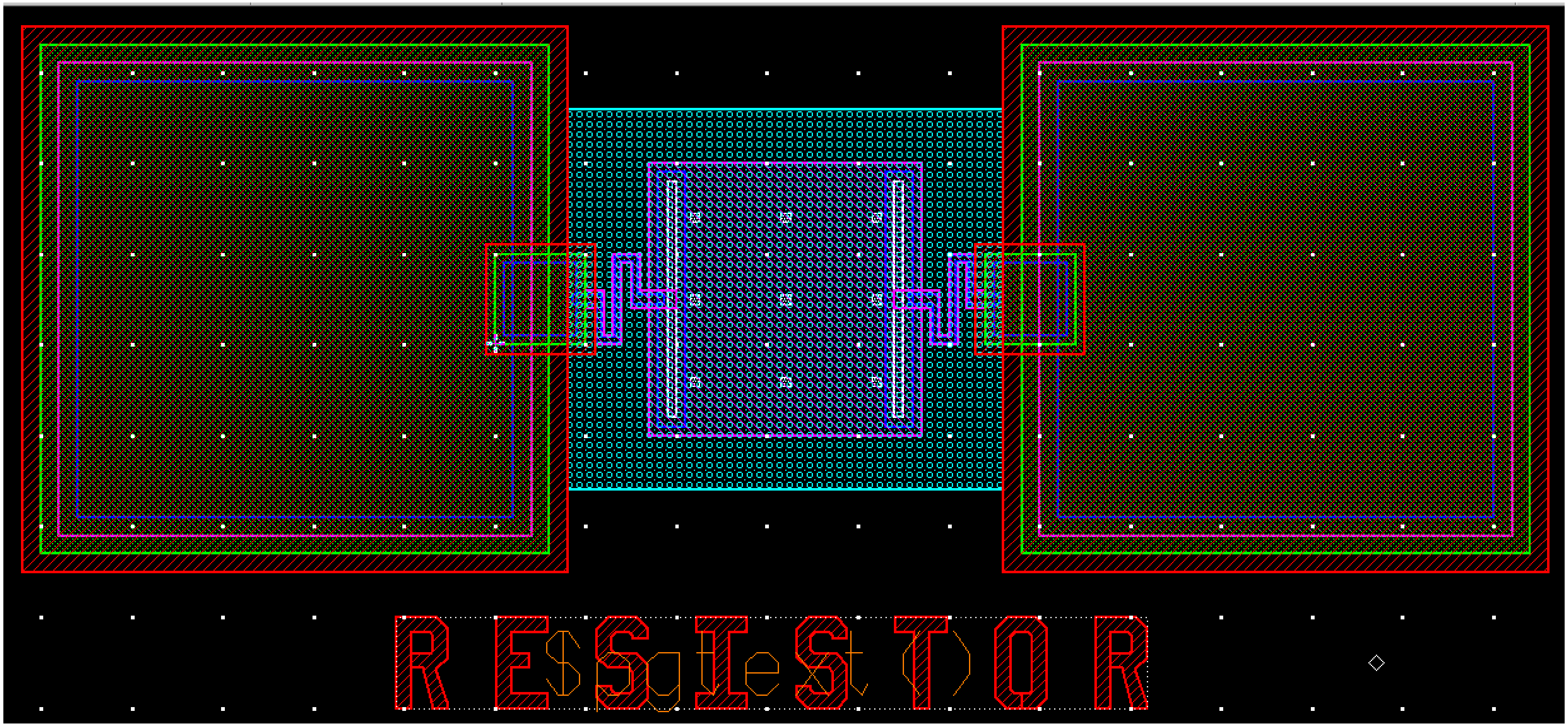
Row Decoder

Column Address

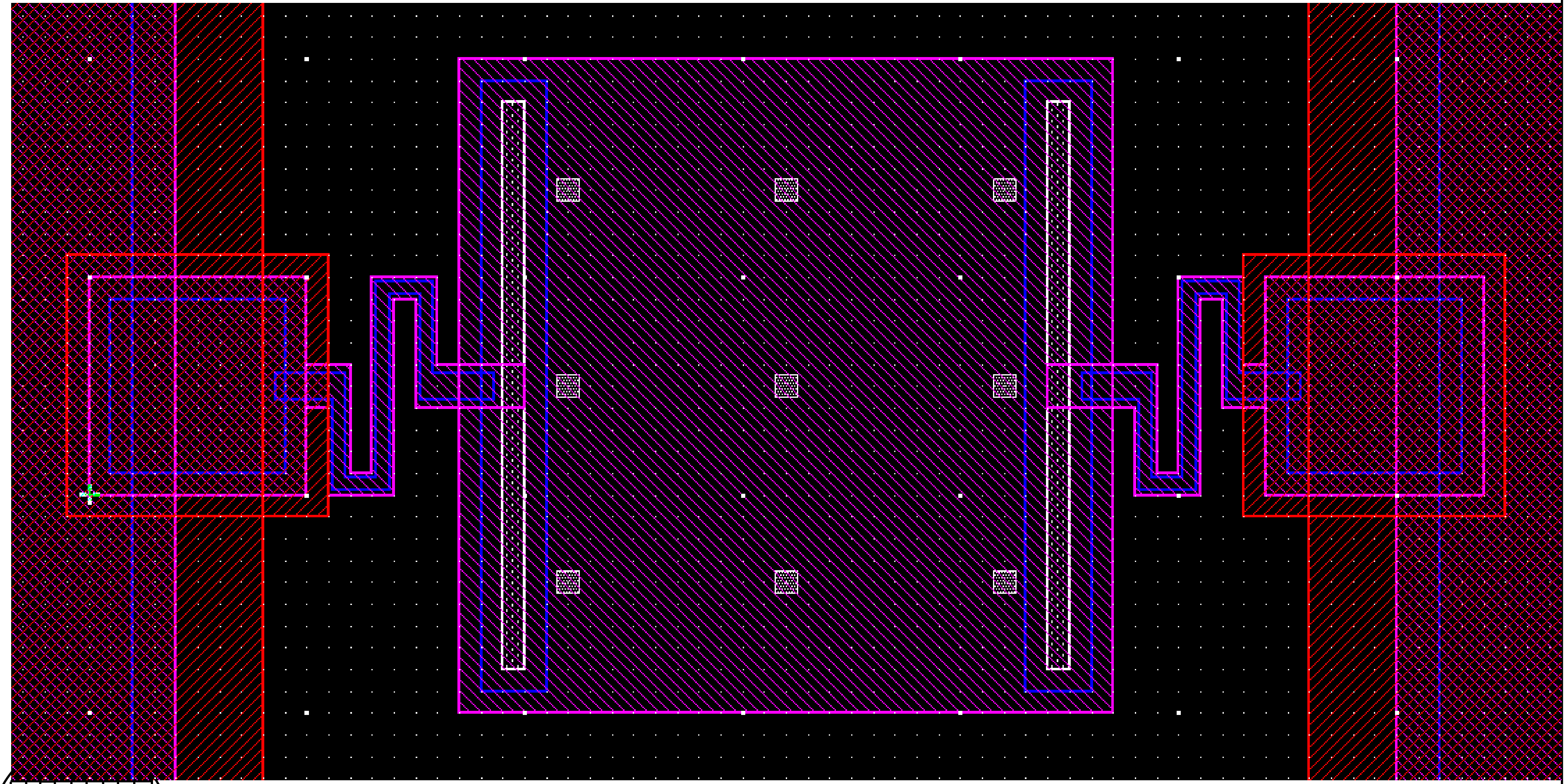
Column Amps & Analog Mux

Serial Output

RESISTOR - BOLOMETER

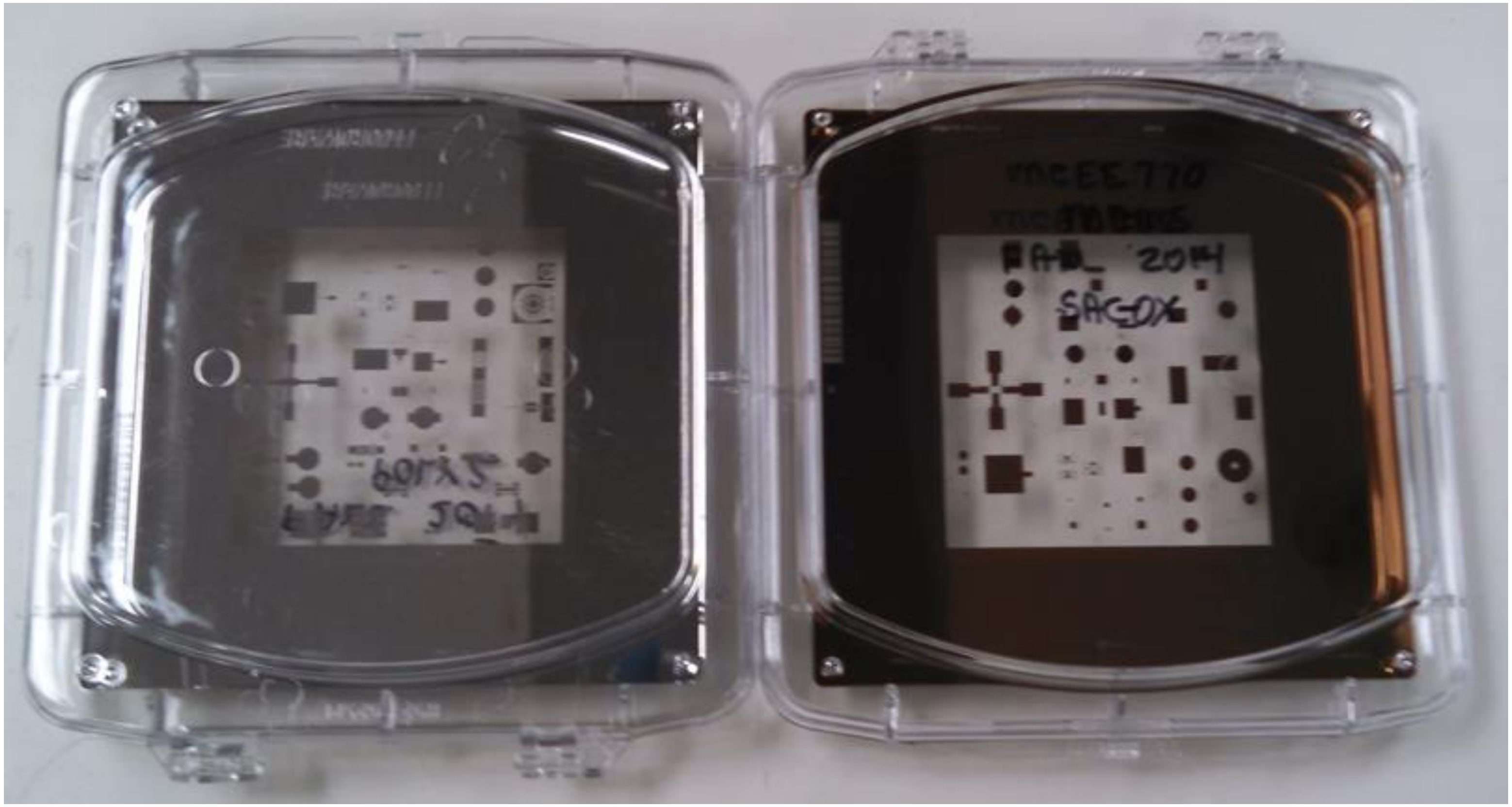


RESISTOR - BOLOMETER

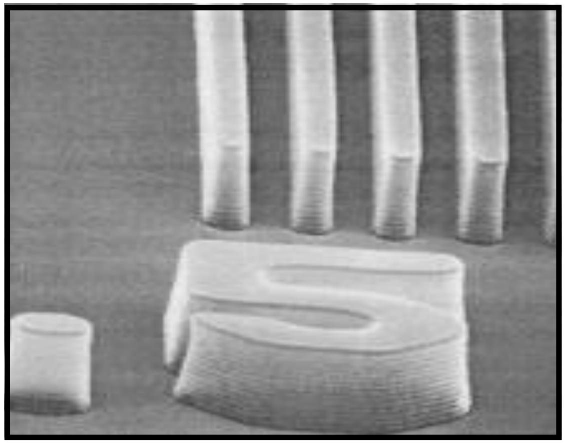


150um x 150um

PICTURE OF PHOTOMASKS



ASML 5500/200



NA = 0.48 to 0.60 variable

σ= 0.35 to 0.85 variable

With Variable Kohler, or Variable Annular illumination

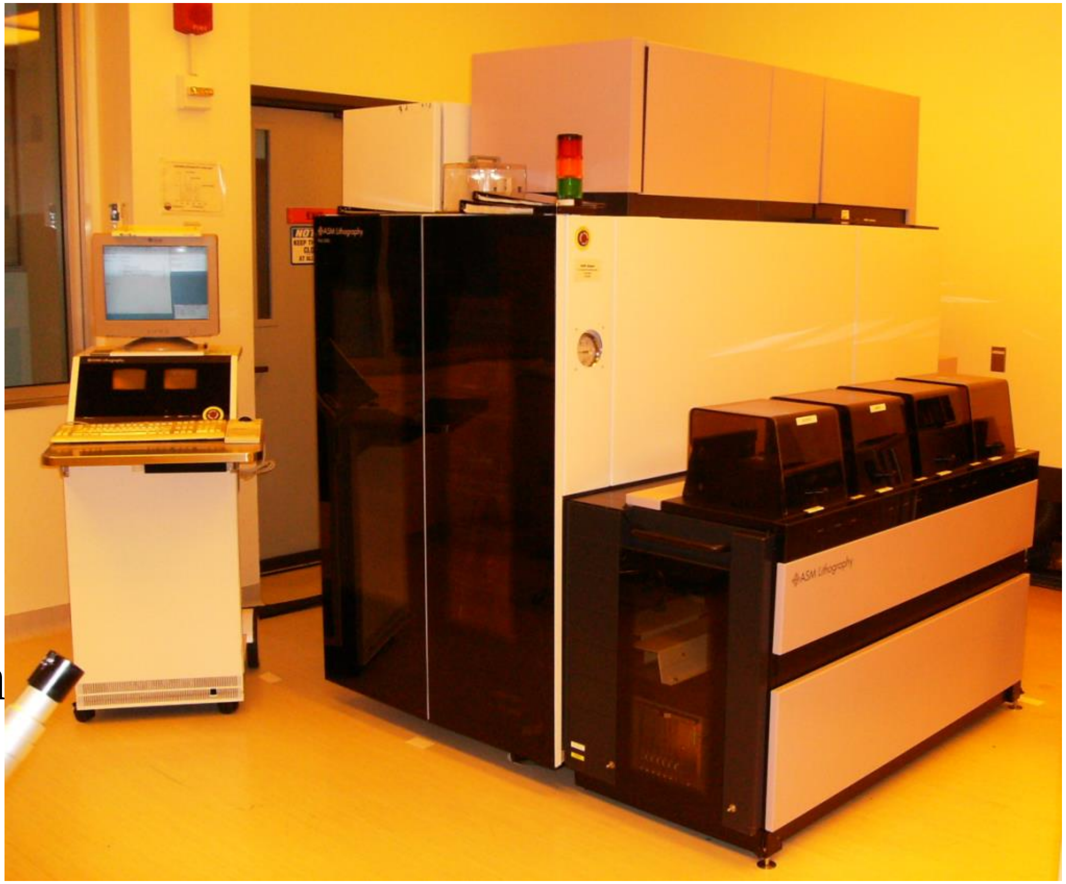
Resolution = K1 λ/NA

= ~ 0.35µm

for NA=0.6, σ =0.85

Depth of Focus = $k_2\ \lambda/(NA)^2$

= > 1.0 µm for NA = 0.6



i-Line Stepper λ = 365 nm

22 x 27 mm Field Size

MICRO BOLOMETER MASK AND STEPPER JOB

Mask Barcode:

Stepper Job: Gottschalk
Level 0 (combi reticle)
Level Clearout (no reticle needed)
Level Poly
Level Alum
Level Via

Level 0	Coat, Develop
Level Poly	Coat, Develop
Level Alum	Coatmtl, Devmtl
Level Via	Coatmtl, Devmtl

SURFACE MEMS 2014 PROCESS

1. Starting wafer
2. PH03 – level 0, Marks
3. ET29 – Zero Etch
4. ID01-Scribe Wafer ID, D1…
5. ET07 – Resist Strip, Recipe FF
6. CL01 – RCA clean
7. OX04 – 6500Å Oxide Tube 4
8. CV01 – LPCVD Poly 5000Å
9. PH03 – level 1 Poly-1
10. ET08 – Poly Etch
11. ET07 – Resist Strip, Recipe FF
12. CL01- RCA clean 2 HF dips
13. CV01- LPCVD Poly 1000Å
14. IM01-P31 2E16 100KeV

~~15. OX04- Anneal Recipe 119~~

16. CV03-TEOS SacOx Dep 1.5um
17. PH03-level 2 SacOx
18. ET06-wet etch SacOx
19. ET07- Resist Strip, Recipe FF
20. CV03-TEOS Etch Stop
21. PH03-Level 3 Anchor-Thick Resist
22. ET06-Wet Etch Oxide
23. ET07-Resist Strip Recipe FF
24. CV01-LPCVD Poly 1.5um
25. PH03-Level 4 No Implant
26. IM01-P31 2E16 100KeV

27; ET07 Resist Strip, Recipe FFF

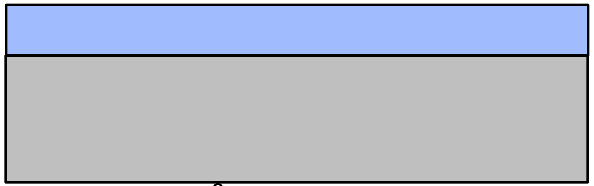
28. OX04-Anneal Recipe 119
29. DE01 Four Point Probe
30. PH03-Level 5 Poly2
31. ET68-STS Etch
32. ET07 Resist Strip, Recipe FFF
33. ET66-SacOx Etch
34. OX05-Consume Etch Stop Poly
35. PH03-Level 6 CC
36. ET06- wet etch BOE
37. ET07 Resist Strip, Recipe FFF
38. CL01-Special
39. ME01 – Sputter Aluminum
40. PH03-Level 7, Metal
41. ET15 – plasma Al Etch
42. ET07 – Resist Strip, Recipe FFF
43. SI01 – sinter Tube 2, Recipe ???
44. SEM1 – SEM Pictures
45. TE01 - Testing

FABRICATION PROCESS

1.

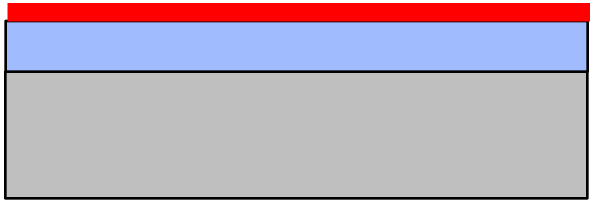
Starting Wafer, zero level marks

2.



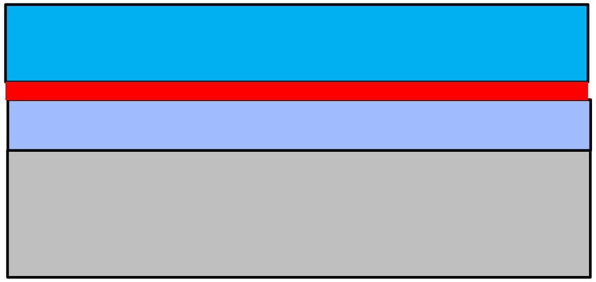
6500Å Field Oxide

3.



1000Å Poly Etch Stop

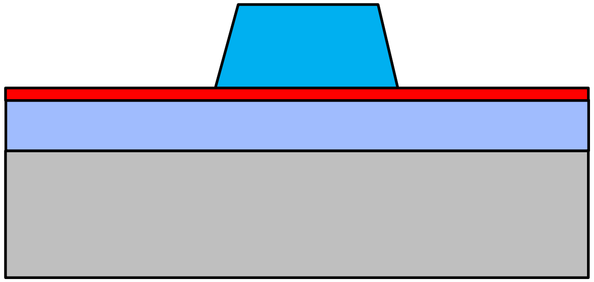
4.



Oxide from TEOS 1.5 µm

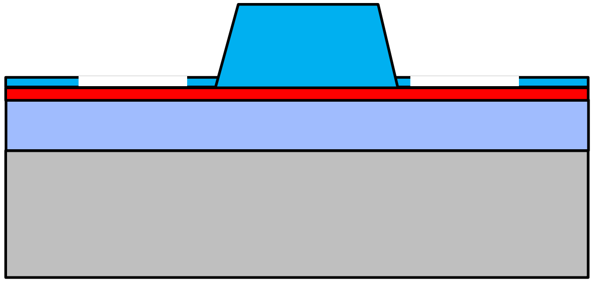
FABRICATION PROCESS

5.



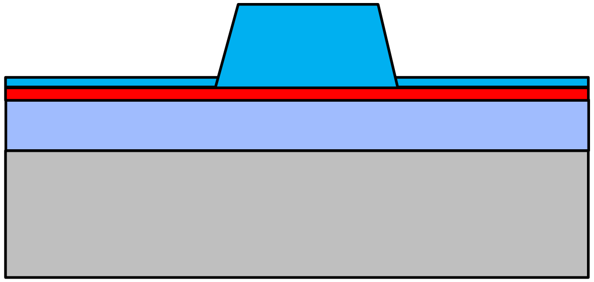
Wet Etch TEOS Sacrificial Oxide

7.



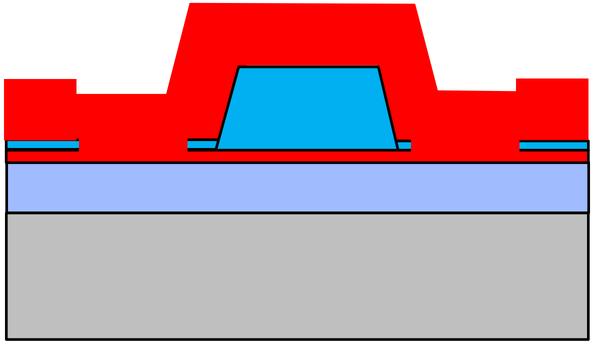
Anchor Holes

6.



TEOS Etch Stop

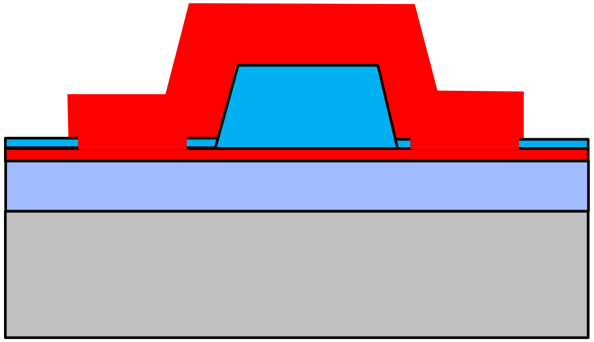
8.



1.5µm Mechanical n+ Poly

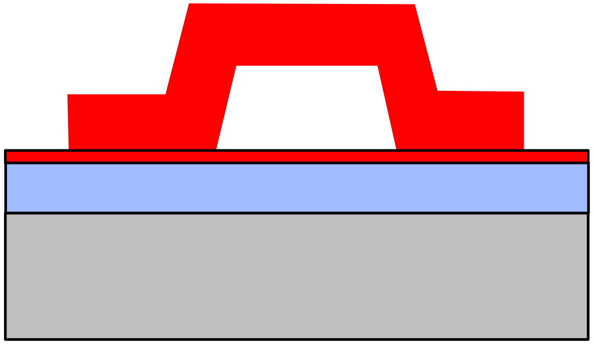
FABRICATION PROCESS

9.



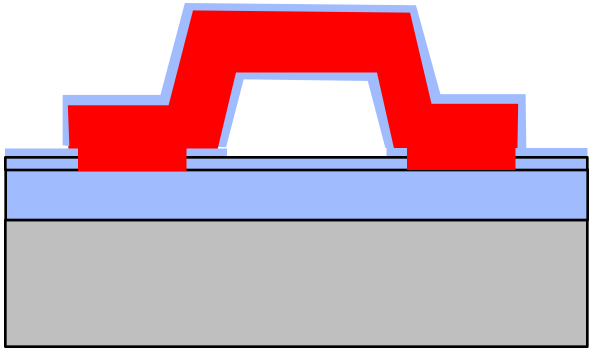
Etch Poly STS Etcher

10.



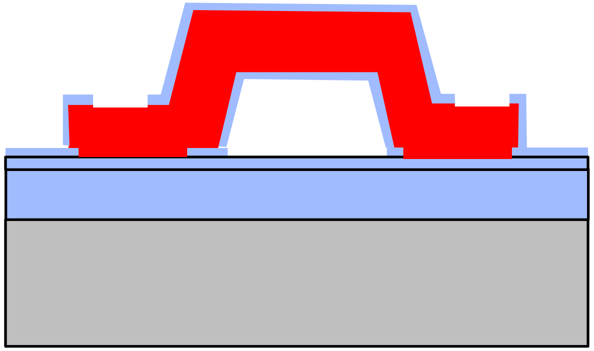
Wet Etch Sacrificial Oxide

11.



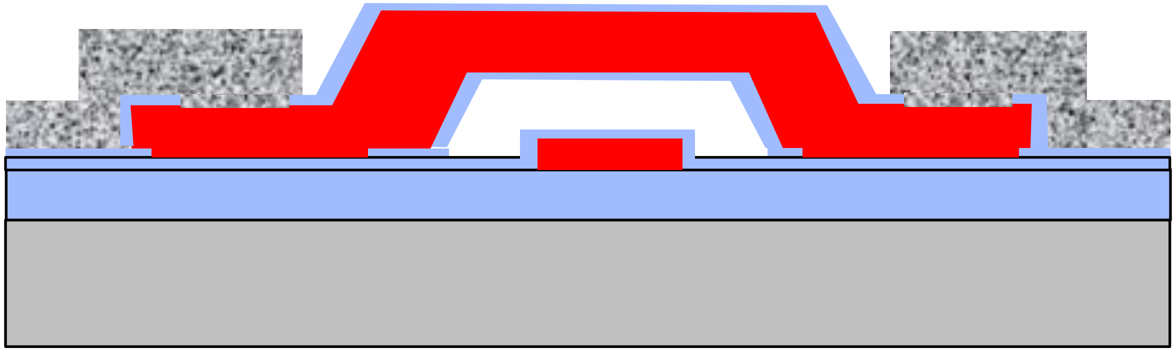
Oxidize Poly

12.



Etch Contact Cuts

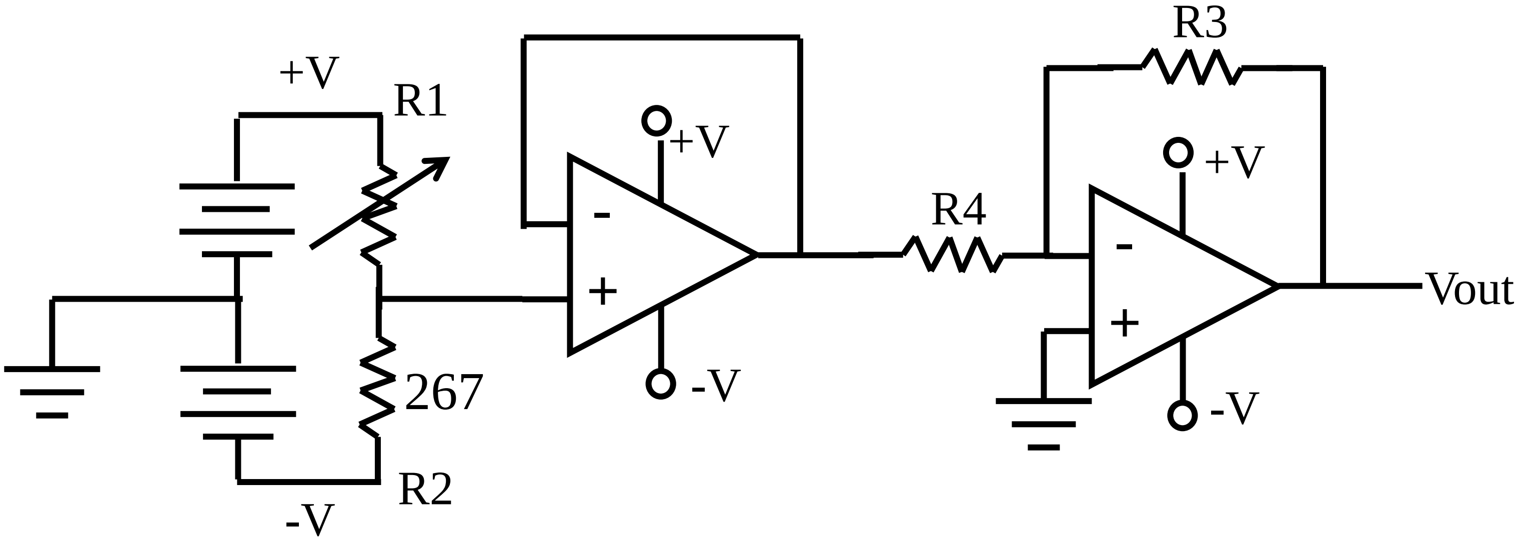
FABRICATION PROCESS



Final Cross Section

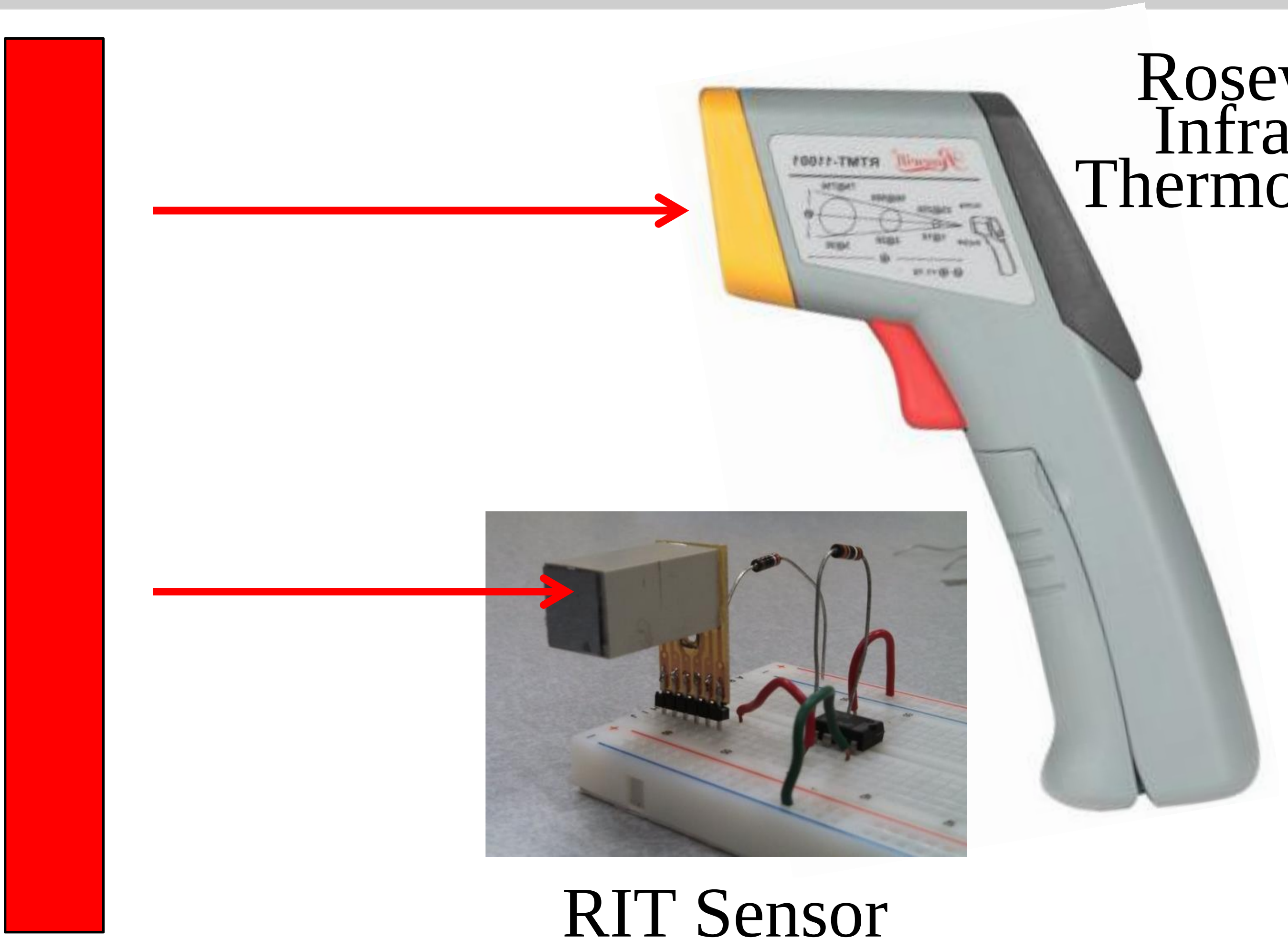
SINGLE RESISTOR TESTING

If R1 is the temperature sensing resistor and R2 is equal value then Vout is zero.



0.004%/°C with gain of 1000 and 100C we get
Vout of V((1.004)/(2.004)-1/2) = V x 0.000998
if V=3 volts then Vout= ~3mV

PACKING AND TESTING



Hot Plate

Rosewell
Infrared
Thermometer

RIT Sensor

SUMMARY

Much more work is needed to finish this study.

TCR of resistors needs to be increased by 1000 over what we measured in the proof of concept study.

New materials such as Ni Oxide has been proposed for the sensor resistors.

REFERENCES

1. "Micro Bolometer." *Wikipedia: The Free Encyclopedia. Wikimedia Foundation, Inc.*, 3 May 2013. Web.
2. Device Electronics for Integrated Circuits, Richard S. Muller, Theodore I. Kamins, Mansun Chan, John Wiley & Sons.,3rd Ed., 2003.
3. Micromachined Transducers, Gregory T. A. Kovacs, McGraw Hill, 1998.

HOMEWORK – MICRO BOLOMETER

1. none