Micro Bolometer

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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
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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
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.

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.

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**

Wien’s Displacement Law

\[ \lambda_{\text{peak}} = \frac{2898 \, \mu m}{T} \]  

From: Micromachined Transducers, Gregory T.A. Kovacs

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

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

- \( h = 6.6262E-34 \, J \, s = 4.1361E-15 \, eV \, s \)
- \( \lambda = \frac{c}{\nu} \)
- \( k=1.38e-23 \, J/K \)
- \( W_\lambda = \text{radiant flux} \)
- \( \varepsilon(\lambda) = \text{emissivity (dimensionless, } \varepsilon=1 \text{ for black body)} \)
Resistance Change (Responsivity, TCR)
Materials
Noise
Active vs Passive
ADSORPTION VERSUS DISTANCE

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

Find % adsorbed for Green light at x=5 \( \mu \text{m} \) and Red light at 5 \( \mu \text{m} \)
SILICON AND POLYSILICON MATERIALS

Single Crystal Silicon

Adsorption coefficient $\alpha$ at $\lambda = 0.5\mu m$ is $1E4$/cm
Adsorption coefficient $\alpha$ at $\lambda = 1.4\mu m$ is $3.2E-8$/cm

Polysilicon

Adsorption coefficient $\alpha$ at $\lambda = 0.5\mu m$ is $5.074E4$/cm
Adsorption coefficient $\alpha$ at $\lambda = 1.2\mu m$ is $1.0E-2$/cm

Amorphous Silicon

Adsorption coefficient $\alpha$ at $\lambda = 0.5\mu m$ is ???E?/cm
Adsorption coefficient $\alpha$ at $\lambda = 3\mu m$ is ???E?/cm
SUSPENDED POLYSILICON RESISTOR
### SUSPENDED POLYSILICON RESISTOR

<table>
<thead>
<tr>
<th>Condition</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Heat</td>
<td>267.41 Ω</td>
</tr>
<tr>
<td>Heat (No Light)</td>
<td>267.42 Ω</td>
</tr>
<tr>
<td>Heat (Uncovered)</td>
<td>267.47 Ω</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Resistor vs. VA:**
  - Type: Linear
  - Slope: 2.847898
  - Intercept (Y): 0.9480467

**Images:**

- Micrograph of the suspended polysilicon resistor.

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**Rochester Institute of Technology**

**Microelectronic Engineering**

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**SUSPENDED POLYSILICON RESISTOR**

Sensitivity = 10mohms/267ohms/100/°C

= 0.004%/°C

Compared to industry TCR’s of 2.0%/°C
SINGLE PIXEL AND READOUT AMPLIFIER

Row Select

Pixel

Readout Amp

Analog

Vout

Vref

Rs

Rref

R1

R2
4x4 PIXEL ARRAY

Row Address → Row Decoder → Column Address → Column Amps & Analog Mux → Serial Output
PICTURE OF PHOTOMASKS
NA = 0.48 to 0.60 variable
σ = 0.35 to 0.85 variable
With Variable Kohler, or Variable Annular illumination
Resolution = \( K_1 \frac{\lambda}{\text{NA}} \)
= \( \sim 0.35 \mu m \)
for NA=0.6, \( \sigma = 0.85 \)
Depth of Focus = \( k_2 \frac{\lambda}{(\text{NA})^2} \)
= \( > 1.0 \mu m \) for NA = 0.6

i-Line Stepper \( \lambda = 365 \) 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

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Starting wafer</td>
</tr>
<tr>
<td>2.</td>
<td>PH03 – level 0, Marks</td>
</tr>
<tr>
<td>3.</td>
<td>ET29 – Zero Etch</td>
</tr>
<tr>
<td>4.</td>
<td>ID01- Scribe Wafer ID, D1…</td>
</tr>
<tr>
<td>5.</td>
<td>ET07 – Resist Strip, Recipe FF</td>
</tr>
<tr>
<td>6.</td>
<td>CL01 – RCA clean</td>
</tr>
<tr>
<td>7.</td>
<td>OX04 – 6500Å Oxide Tube 4</td>
</tr>
<tr>
<td>8.</td>
<td>CV01 – LPCVD Poly 5000Å</td>
</tr>
<tr>
<td>9.</td>
<td>PH03 – level 1 Poly-1</td>
</tr>
<tr>
<td>10.</td>
<td>ET08 – Poly Etch</td>
</tr>
<tr>
<td>11.</td>
<td>ET07 – Resist Strip, Recipe FF</td>
</tr>
<tr>
<td>12.</td>
<td>CL01- RCA clean 2 HF dips</td>
</tr>
<tr>
<td>13.</td>
<td>CV01- LPCVD Poly 1000Å</td>
</tr>
<tr>
<td>14.</td>
<td>IM01-P31 2E16 100KeV</td>
</tr>
<tr>
<td>15.</td>
<td>OX04– Anneal Recipe 119</td>
</tr>
<tr>
<td>16.</td>
<td>CV03-TEOS SacOx Dep 1.5um</td>
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<tr>
<td>17.</td>
<td>PH03-level 2 SacOx</td>
</tr>
<tr>
<td>18.</td>
<td>ET06-wet etch SacOx</td>
</tr>
<tr>
<td>19.</td>
<td>ET07- Resist Strip, Recipe FF</td>
</tr>
<tr>
<td>20.</td>
<td>CV03-TEOS Etch Stop</td>
</tr>
<tr>
<td>21.</td>
<td>PH03-Level 3 Anchor-Thick Resist</td>
</tr>
<tr>
<td>22.</td>
<td>ET06-Wet Etch Oxide</td>
</tr>
<tr>
<td>23.</td>
<td>ET07-Resist Strip Recipe FF</td>
</tr>
<tr>
<td>24.</td>
<td>CV01-LPCVD Poly 1.5um</td>
</tr>
<tr>
<td>25.</td>
<td>PH03-Level 4 No Implant</td>
</tr>
<tr>
<td>26.</td>
<td>IM01-P31 2E16 100KeV</td>
</tr>
<tr>
<td>27.</td>
<td>ET07 Resist Strip, Recipe FFF</td>
</tr>
<tr>
<td>28.</td>
<td>OX04–Anneal Recipe 119</td>
</tr>
<tr>
<td>29.</td>
<td>DE01 Four Point Probe</td>
</tr>
<tr>
<td>30.</td>
<td>PH03-Level 5 Poly2</td>
</tr>
<tr>
<td>31.</td>
<td>ET68-STS Etch</td>
</tr>
<tr>
<td>32.</td>
<td>ET07 Resist Strip, Recipe FFF</td>
</tr>
<tr>
<td>33.</td>
<td>ET66-SacOx Etch</td>
</tr>
<tr>
<td>34.</td>
<td>OX05-Consume Etch Stop Poly</td>
</tr>
<tr>
<td>35.</td>
<td>PH03-Level 6 CC</td>
</tr>
<tr>
<td>36.</td>
<td>ET06-wet etch BOE</td>
</tr>
<tr>
<td>37.</td>
<td>ET07 Resist Strip, Recipe FFF</td>
</tr>
<tr>
<td>38.</td>
<td>CL01-Special</td>
</tr>
<tr>
<td>39.</td>
<td>ME01 – Sputter Aluminum</td>
</tr>
<tr>
<td>40.</td>
<td>PH03-Level 7, Metal</td>
</tr>
<tr>
<td>41.</td>
<td>ET15 – plasma Al Etch</td>
</tr>
<tr>
<td>42.</td>
<td>ET07 – Resist Strip, Recipe FFF</td>
</tr>
<tr>
<td>43.</td>
<td>SI01 – sinter Tube 2, Recipe ???</td>
</tr>
<tr>
<td>44.</td>
<td>SEM1 – SEM Pictures</td>
</tr>
<tr>
<td>45.</td>
<td>TE01 - Testing</td>
</tr>
</tbody>
</table>
FABRICATION PROCESS

1. Starting Wafer, zero level marks

2. 6500Å Field Oxide

3. 1000Å Poly Etch Stop

4. Oxide from TEOS 1.5 \( \mu m \)
FABRICATION PROCESS

5. Wet Etch TEOS Sacrificial Oxide

6. TEOS Etch Stop

7. Anchor Holes

8. 1.5μm Mechanical n+ Poly
FABRICATION PROCESS

9. Etch Poly STS Etcher

11. Oxidize Poly

10. Wet Etch Sacrificial Oxide

12. Etch Contact Cuts
Final Cross Section
If R1 is the temperature sensing resistor and R2 is equal value then Vout is zero.

\[ V_{out} = V \times \frac{(1.004)/(2.004)-1/2}{2.004} = V \times 0.000998 \]

if V=3 volts then Vout= ~3mV

0.004%/°C with gain of 1000 and 100°C we get
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


HOMEWORK – MICRO BOLOMETER

1. none