Design of CMOS-MEMS Infrared Emitter Arrays
Cheng Zhengxi and Hiroshi Toshiyoshi

We present a new design of CMOS-MEMS broadband infrared (IR) emitter arrays with metamaterial absorbers (MAs) integrated by the CMOS back-end of line (BEOL) process of 0.5 μm 2-Poly-3-Metal CMOS rules. Three different shapes of micro emitters are designed to balance the trade-off relationship between performance and yield. Tri-layer metal-insulator-metal (MIM) and four-layer insulator-metal-insulator-metal (IMIM) MAs are adopted to broaden the emissivity waveband and to enhance the emissivity.

Introduction

Infrared Gas Sensor

Schematic of hyper-spectral IR gas sensor structure

Objectives of design: MEMS IR emitter

For high IR emissivity, we use metamaterial absorbers integrated by CMOS back end of line (BEOL) process on the top of CMOS MEMS IR emitters

Process

Geometries

Three shapes emitters

Thin film stacks of micro emitters

a) Tri-layer stack of common emitter
b) Emitter integrated with IMIM MA
c) Emitter integrated with MIM MA

Result

Devices after CMOS process: 8×8 scale array, pixels

Tri-layer stack of common emitter integrated with IMIM-MA

Power-temperature relationship

Dynamic thermal responses

Emissivity spectra

Dynamic radiation responses

Table 1: Thermal properties and radiation properties of IR emitters

<table>
<thead>
<tr>
<th>Emitters</th>
<th>Thermal Conductance (10⁻⁶ W/K)</th>
<th>Thermal Mass (10⁴ J/K)</th>
<th>Thermal Time Constant (ms)</th>
<th>Radiance Rise Time (ms)</th>
<th>Radiance Fall Time (ms)</th>
<th>Power Emission &amp; K Temperature Increment (W/K/°K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I common</td>
<td>0.74</td>
<td>1.96</td>
<td>1.43</td>
<td>3.8</td>
<td>2.6</td>
<td>0.74</td>
</tr>
<tr>
<td>Type II common</td>
<td>0.74</td>
<td>1.97</td>
<td>1.45</td>
<td>3.8</td>
<td>2.6</td>
<td>0.73</td>
</tr>
<tr>
<td>Type III common</td>
<td>2.48</td>
<td>0.90</td>
<td>0.35</td>
<td>1.2</td>
<td>0.8</td>
<td>0.81</td>
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<tr>
<td>Type III with IMIM</td>
<td>1.10</td>
<td>3.11</td>
<td>2.82</td>
<td>8.3</td>
<td>2.4</td>
<td>1.14</td>
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<tr>
<td>Type III with IMIM</td>
<td>1.11</td>
<td>3.06</td>
<td>2.76</td>
<td>7.5</td>
<td>2.2</td>
<td>1.13</td>
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<tr>
<td>Type III with IMIM</td>
<td>4.54</td>
<td>2.74</td>
<td>0.60</td>
<td>1.6</td>
<td>1.3</td>
<td>4.66</td>
</tr>
</tbody>
</table>

Conclusion

CMOS-MEMS broadband IR emitter arrays integrated with MAs are designed by using CSMC 0.5 μm CMOS process. Thermal radiation simulation results show that Type-III common IR emitters and Type-III emitter with IMIM-MA function upwards of 454 Hz and 344 Hz. Simulated absorption spectra show that MIM-MAs and IMIM-MAs enhance IR absorbance in 2-3 μm waveband, and broaden the IR absorption to 20 μm.

Contact: czx@iis.u-tokyo.ac.jp
