Design of CMOS-MEMS Infrared Emitter Arrays

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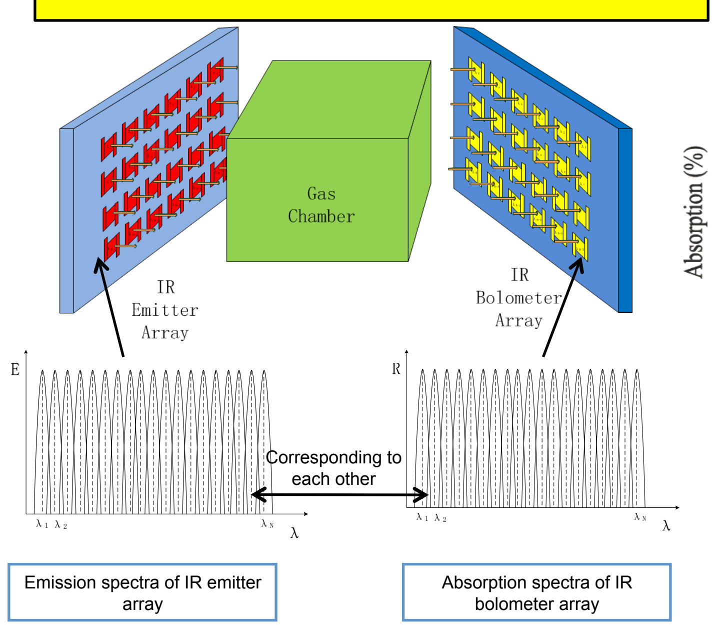
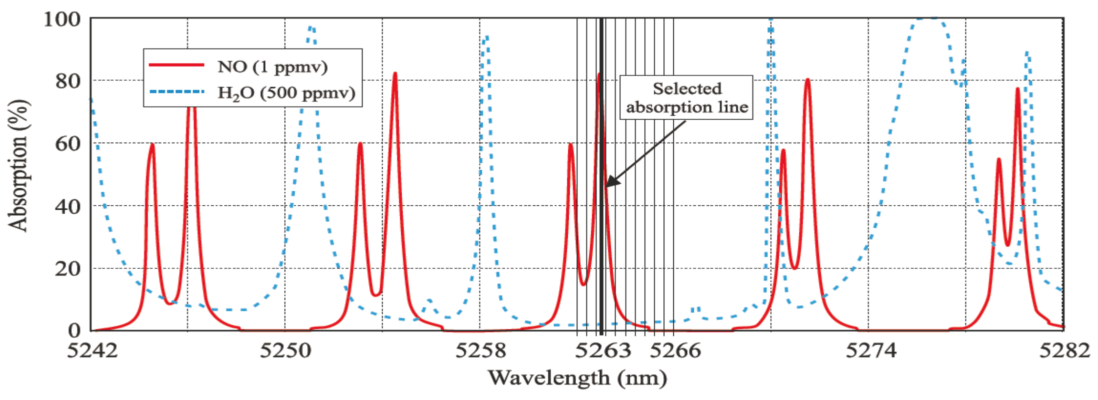
We present a new design of CMOS-MEMS broadband infrared (IR) emitter arrays with metamaterial absorbers (MAs) integrated by the CMOS back-end of line (BEOL) process of 0.5 μm 2-Poly-3-Metal CMOS rules. Three different shapes of micro emitters are designed to balance the trade-off relationship between 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



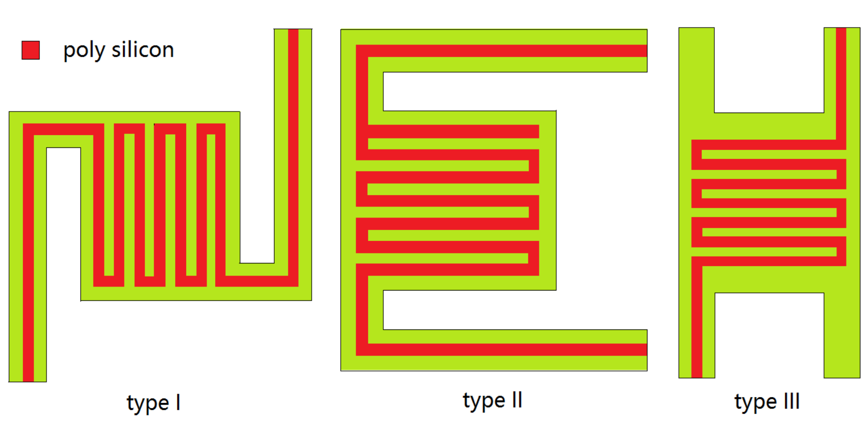
IR absorption spectra used as a fingerprint of gas molecules

Objectives of design: MEMS IR emitter

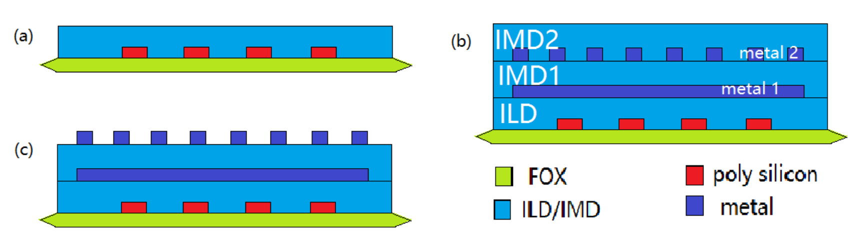
For high IR emissivity, we use metamaterial absorbers integrated by CMOS back end of line (BEOL) process on the top of CMOS MEMS IR emitters

Process

Geometries



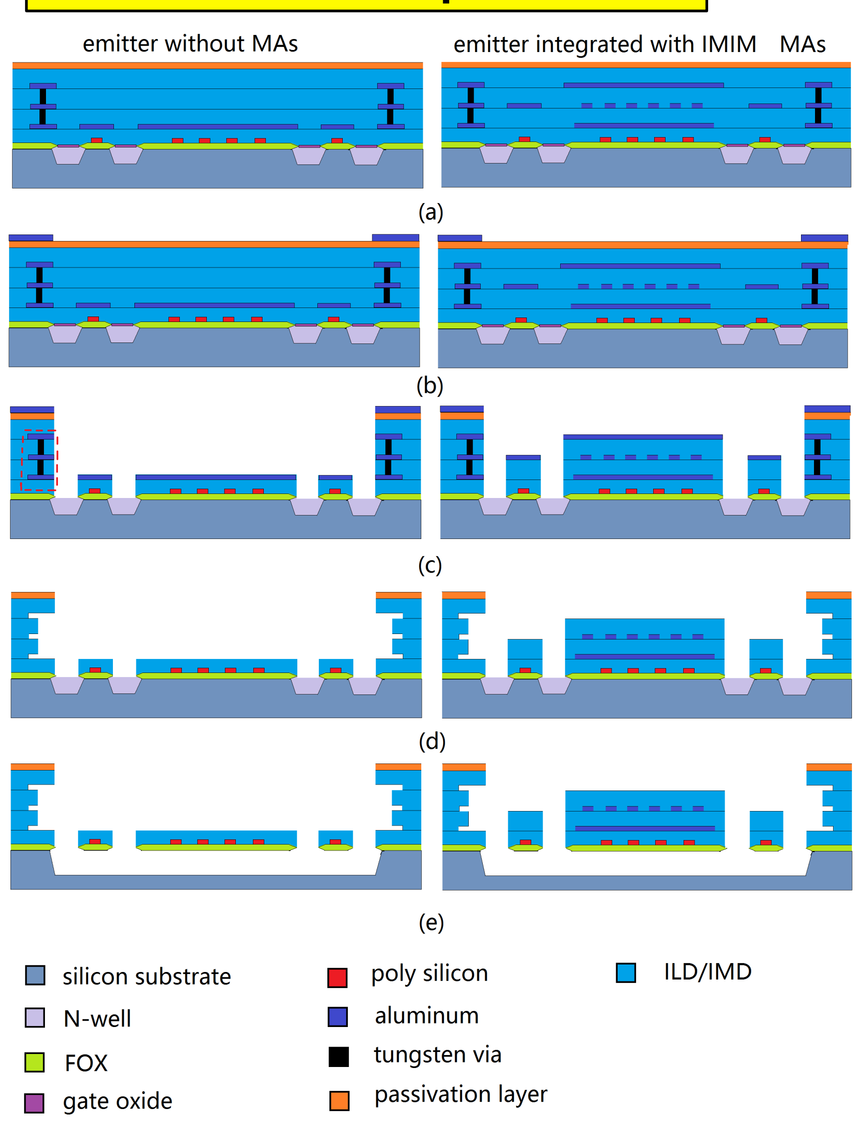
Three shapes emitters



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

Post-CMOS process

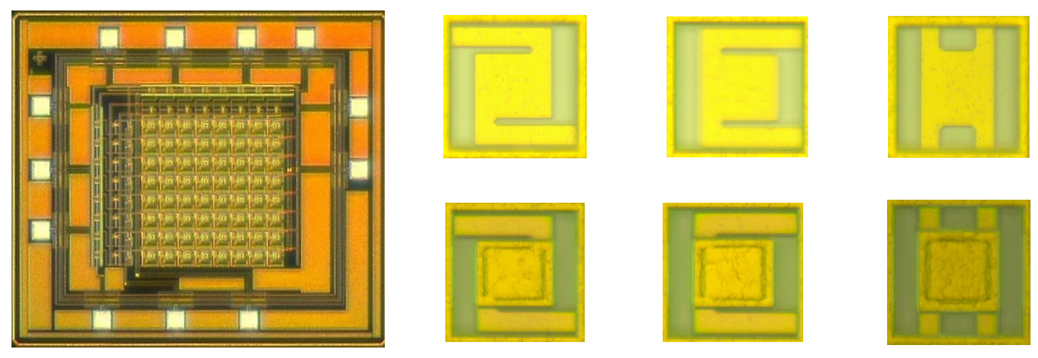


Cheng Zhengxi and Hiroshi Toshiyoshi: "A design of integrated CMOS-MEMS infrared emitter arrays," IEICE Electronics Express, Vol. 13 No. 7 pp. 1-10 (2016).

Cheng, Z., and Toshiyoshi, H.: 'Design of CMOS-MEMS Infrared Emitter Arrays'. Proc. 11th Annual IEEE International Conference on Nano/Micro Engineered and Molecular Systems (IEEE-NEMS 2016), Matsushima and Sendai, Japan, 17-20 April, 2016

Result

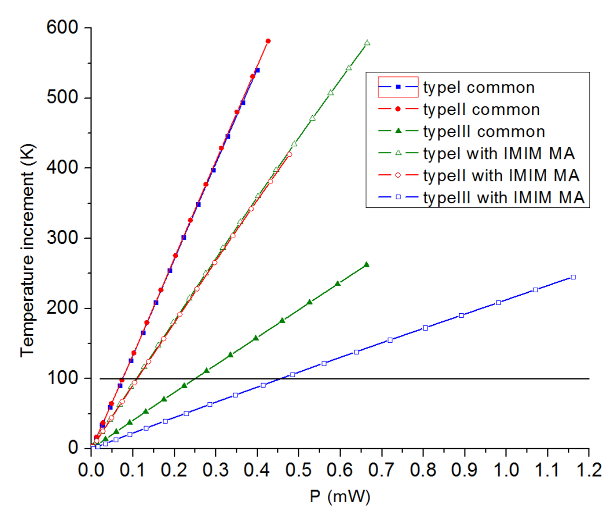
Devices after CMOS process: 8×8 scale array, pixels



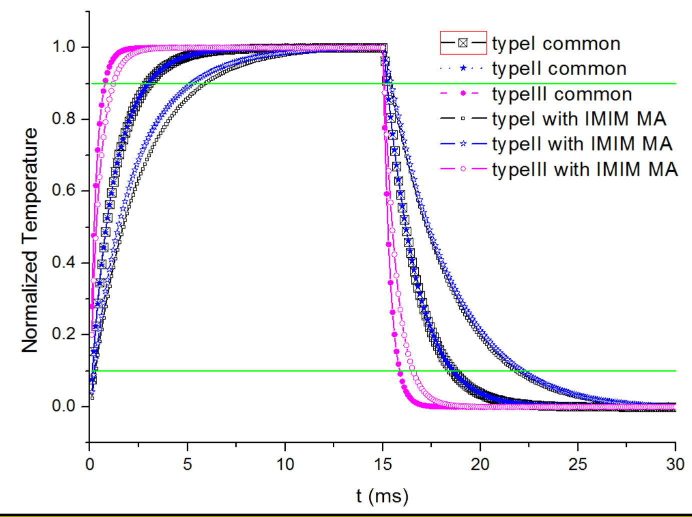
Type I *Type II* *Type III*

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

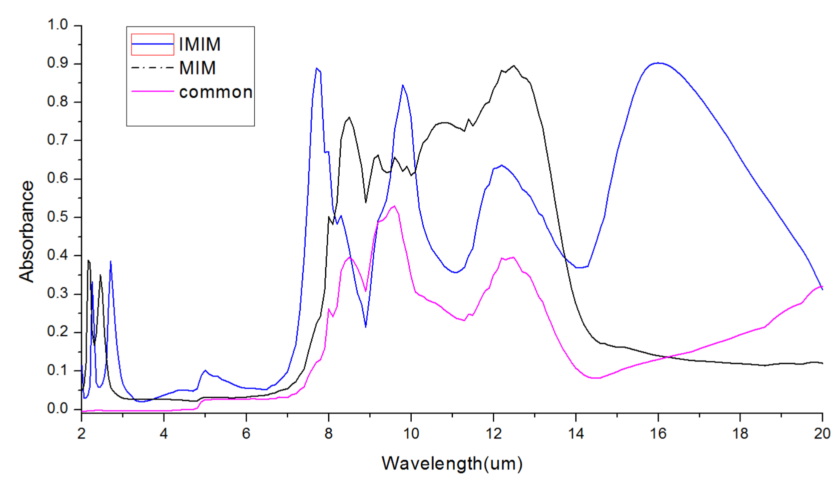
Power-temperature relationship



Dynamic thermal responses



Emissivity spectra



Dynamic radiation responses

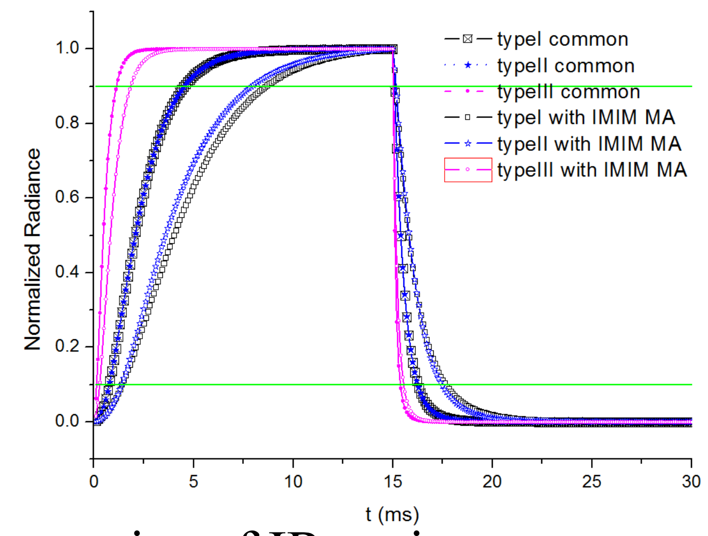


Table 1: Thermal properties and radiation properties of IR emitters

Emitters	Thermal Conductance (10^{-6} W/K)	Thermal Mass (10^{-9} J/K)	Thermal Time Constant (ms)	Radiance Rise Time (ms)	Radiance Fall Time (ms)	Power for per K temperature increment (10^{-6} W/K)
Type I common	0.74	1.06	1.43	3.8	2.6	0.74
Type II common	0.74	1.07	1.45	3.8	2.6	0.73
Type III common	2.48	0.90	0.35	1.2	1.0	2.51
Type I with IMIM	1.10	3.11	2.82	8.3	2.4	1.14
Type II with IMIM	1.11	3.06	2.76	7.5	2.2	1.13
Type III with IMIM	4.54	2.74	0.60	1.6	1.3	4.66

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.

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