Metasurface configuration for selective infrared radiation source

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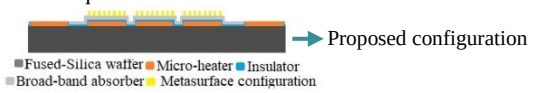
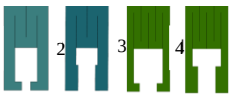
Aim: Our aim is to integrate a micro-heater configuration with a metasurfaces structure in order to develop IR sources with high emissivity control based on a narrow band absorber. The emission control is achieved by tailoring a metasurface to attain nearly 100% narrow-band absorption at desired IR domain wavelengths. The heater is used also as a back-reflector, in order to simplify the technology process, and is composed of 80nm thick platinum layer in meander configuration, the line width between the meander is 10µm and the resistor area is 1 square cm.



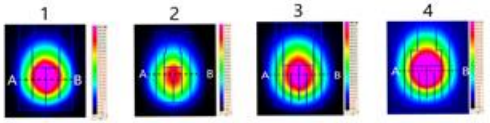
Application: IR ultra selective sources or gas sensors:Metamaterials have specific properties such as negative permittivity, permeability and refraction index, allowing them to be used for beam shaping or for realization of a perfect absorber for photonic and optoelectronic applications. With a specifically tailored metamaterial one can achieve an absorption value close to 1 in any frequency domain [1, 2]. Furthermore, Kirchhoff law states that the emissivity of a material is equal to the absorption at equilibrium [1] which makes this type of structures ideal for our designated application. Furthermore, the most frequent toxically gas molecules present in industrial infrastructures are: methane (CH_4), carbon oxides (CO_2, CO), azote oxides (NO_2, NO), ozone (O_3), etc. The absorption wavelengths of each one of these gases are close to one another, therefore, for work security and health purposes it is necessary to develop highly sensitive sensors and emission sources for tight IR wavelength intervals [3].

Microheater in meander configuration

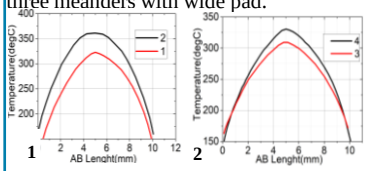


Selected geometry for the resistive meander configuration.

❖ Steady-state Thermal Analysis



Thermal images obtained with the IR camera for the four micro-heaters: 1 - two meanders with short pad, 2 - two meanders with wide pad, 3 – three meanders with narrow pad, 4 - three meanders with wide pad.

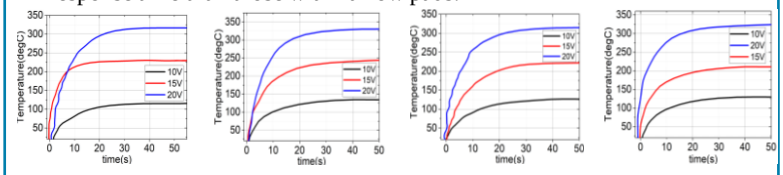


Temperature variation measured with the IR camera along the A-B lines: **1** – micro-heaters with two meanders (black line – narrow pad, red line – wide pad), **2** – micro-heaters with three meanders (black line – wide pad, red line – narrow pad).

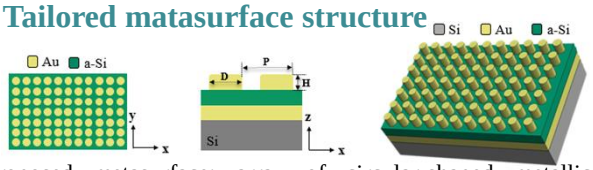
- The temperature variations along the A-B line indicate that all the heaters reach the targeted temperature (300° C) for the IR emitter. However, the best uniformity over the entire camera is obtained for the heater with three meanders and large pads.

❖ Transient thermal analysis

- Three voltages are applied to the four micro-heaters (10 V, 15 V, and 20V respectively) for 60 seconds.
- The temperature variation in the analyzed point for the four micro-heaters are resented below
- According to these graphs, the wide pads micro-heaters show a lower response time than those with narrow pads.

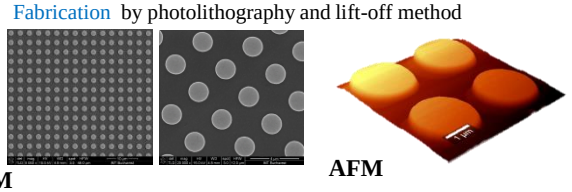


Tailored matasurface structure



Proposed metasurface: array of circular-shaped metallic resonators (gold) with diameter in the order of micrometres, configures on a amorphous silicon substrate. The role of this configuration is to improve the light absorption within a narrow band interval in the IR domain by modelling the geometrical parameter of the array (diameter, period).

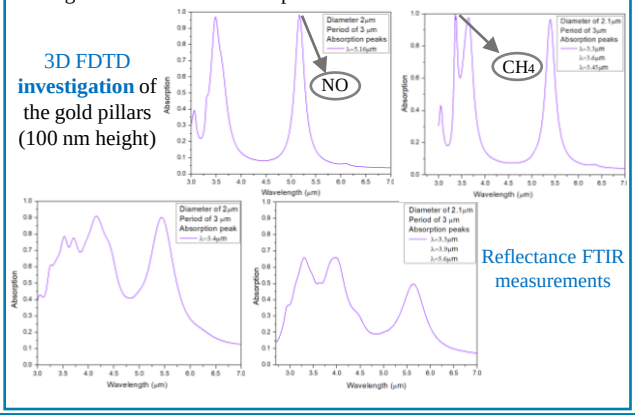
❖ Fabrication by photolithography and lift-off method



SEM **AFM**

❖ Dependence of the absorption as a function of the metasurface geometrical and material parameters

3D FDTD **investigation** of the gold pillars (100 nm height)



Reflectance FTIR measurements

Conclusion

- Calculated, fabricated and measured a microheater based on a meander platinum resistor.
- We designed and fabricated metasurfaces for IR sources with emissivity centred at 3.3µm, 3.6µm and 5.4µm wavelengths suitable for selective emissivity IR sources or gas sensing applications.
- Next step is to place the absorbent metasurface on top of the meander resistor source. The specifically tailored metasurface, placed directly over the heater, absorbs all the radiation spectrum emitted and will emit only the wavelengths for which it is designed

References

[1] - Weiren Zhu et al., Appl Phys A, 102: 147–151, 2011.
[2] - Xianliang Liu, et al., PRL 107, 2011.
[3] Kumar, P. et al., Environment international, 75, pp.199-205.

Acknowledgment

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