



Optimization of a new microbolometer IR detector in standard CMOS technology

Nasimeh MORADI^{1,*}, Zahra KHADEM², Ahmad AFİFİ³

¹M.Sc. Student, Arak Branch, Islamic Azad University, Arak, Iran

²M.Sc., Department of ICT, Maleke Ashtar University

³Assistant professor of Maleke Ashtar University, university complex of power electronic, power and electronic engineering group

Received: 01.02.2015; Accepted: 05.05.2015

Abstract. This paper reports a new microbolometer structure with the CMOS n-well layer as the active element and the metal layer as intermediate layer on supporting arms. Due to thermal flux into the microbolometer, thermal variation occurs within it that leads to the variation of resistivity. The more thermal variation, the more microbolometer performance. Various materials have been used for fabrication of bolometers that one could outperforms the performance of bolometers by selecting an appropriate materials for active and intermediate layers on supporting arm. Detailed thermal simulations in ANSYS were performed to obtain an optimized structure. Maximum specific detectivity has been calculated 1334×10^9 cmHz^{1/2}/W with a responsivity of 32721 V/W.

Key Words: infrared beam, microbolometer, specific detectivity, responsivity

1. INTRODUCTION

Infrared detectors include two types: photonic and thermal detectors. Low cost thermal detectors are used for applications that don't need high sensitivity. In this type, a thermistor is used as sensitive element. Due to advantages such as low cost, light weight, low power and high spectrum response and long-term application, extensive studies have been conducted for developing giant arrays with low cost for various applications such as commercial use of them for improving night vision of drivers and fire fighters [1, 5].

One of main critical problems for developing low cost detectors is integrating and consistency with cmos technology. The most known methods for uncooled infrared imaging is use of microbolometer structures, in which, infrared radiation increases the temperature of a body and varies its resistivity. Various materials have been used for microbolometer [3]. Vanadium oxide (VO_x) is a substance that is known and has been used extensively. This substance has a high value of TCR, that is, 2-3 % /k. he main disadvantage of VO_x is that is not a standard material in IC manufacturing processes.

2. MAIN MICROBOLOMETER PARAMETERS

Every microbolometer includes a series of structural and exerting parameters that each of them plays an essential role in microbolometer performance. The criterion of comparison between detectors is their D* (specific detection rate). This parameter shows signal to noise ratio of a detector. The more D* for a detector with a known wavelength of radiated beam, the more sensitivity of detector, therefore, the detector has this capability to detect weaker signals:

$$D^* = \frac{R_v}{V_n} \sqrt{A \times \Delta f} \quad (1)$$

*Corresponding author. Email address: moradi.nasime@yahoo.com

Where;

Δf is width of the band, A bolometer cross section, R_v responsivity of the system, V_n overall noise of the system and D^* is specific detectivity.

R_v is calculated as follows:

$$R_v = \frac{\eta \cdot \alpha \cdot R \cdot I_b}{G \cdot \sqrt{1 + 4 \cdot \pi^2 \cdot f^2 \cdot t^2}} \quad (2)$$

Where;

η is absorption coefficient, α thermal resistivity coefficient, R resistivity, I_b bias current, G thermal conduction, f interruption current and t is time constant. Value of time constant is calculated from following relation:

$$t = c/a \quad (3)$$

Where,

C and G are thermal capacity and thermal conduction, respectively. Dependence of resistivity and thermal variation is calculated by the following formula [2]:

$$\alpha = \frac{1}{R} \times \frac{dR}{dT} \quad (4)$$

3. THE STRUCTURE OF N-WELL MICROBOLOMETER

The performance of n-well microbolometer could be improved by various structures, supporting arms and different absorbers. Microbolometer dimensions is $50 \times 50 \mu\text{m}$ that is consistent with high resolution of imaging, but this small size reduces the fill factor of detector. In this type of microbolometer, n-well layer is surrounded by an empty region that allow the underlying silicon disk has been eroded for decreasing thermal conduction and increasing responsivity. There is an oxide-metal layer on the n-well layer that absorbs radiation power, consequently its temperature rises and, as a results, its resistivity that depends on resistivity temperature coefficient will vary. Two supporting arms placed in both sides of n-well layer. Electrical contact with n-well layer is established through intermediate layer. Supporting arms should be as large and narrow as possible. In addition, material used on the supporting arms should have a high thermal conduction coefficient.

At first, metal is considered as intermediate layer with conduction coefficient of 181 W/m.K . In addition, thermal conduction coefficient plays an important role in microbolometer performance. Due to thermal flux into the microbolometer, thermal variation occurs within it that leads to the variation of resistivity. The more temperature variation as a result of thermal flux, the more resistivity variation and microbolometer have a higher sensitivity. One of the best way of improving bolometer performance is varying material type, so that material with less thermal conduction in intermediate layer (better thermal insulation), develops more temperature difference in bolometer.

4. OPTIMIZATION AND SIMULATION OF MICROBOLOMETER

Performance of n-well microbolometer is affected by dimensional design parameters including pixels size, distance between arms and n-well layer, length of arms and so on. Materials of main layer, arms and absorbing layer have a direct influence on microbolometer performance [6].

Characteristics and required conditions for analysis is listed in table 1. At first, metal has been used as intermediate layer and, critically has been analyzed, in ANSYS software.

Table 1. Microbolometer characteristics for ANSYS analysis.

Characteristic	value
Absorbing layer	0/05× mm0/03 mm
Arm’s cross section of overall supporting area	0/0025 mm×0/00125mm
Length of supporting arm	2×0/05mm
Width distance between arm and absorbing	0/004 mm,0/007 mm
Microbolometer layer thickness	0.005 mm
Main body	n-well
bulk thermal conduction coefficient	140 (W/mK)
Arms	Metal
Arms thermal conduction coefficient	181 (W/mK)
Internal thermal source	2500 (W/m^2)
Reference temperature	293.15 K
Induced temperature difference	37.4K

The results of microbolometer analysis with mentioned characteristics of above table analyzed with ANSYS software has been shown in figure 1. In this sample, a n-well layer and metal layer as intermediate have been selected for analysis.

As shown in the figure, induced temperature difference for this sample is 4.37 degree for 293.15 as minimum to 297.52 degree of Kelvin as maximum temperature.

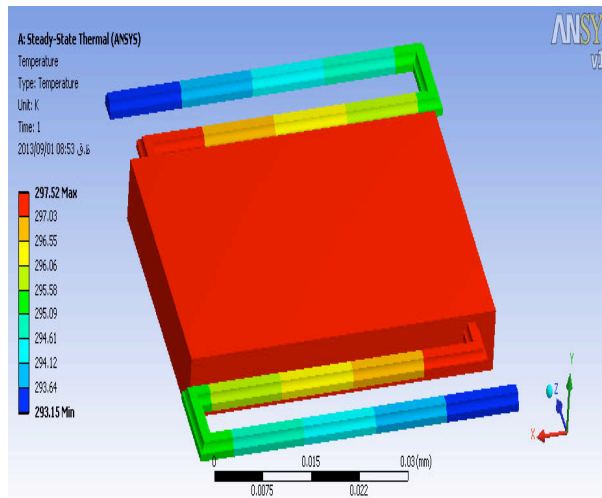


Figure 1. Results of simulation analysis with ANSYS.

In this case, detectivity and responsivity values are 1.7571×10^9 cmH^{1/2}/W and 3833.6 V/W, respectively. In this paper, there are several alternatives for intermediate layer: metal, poly-silicon and nitride. Advantage of metal layer is that it has a low value of electrical resistivity that, in turn, reduces noise. But, it has a high thermal conduction coefficient. Poly-silicon layer and nitride have high value of electrical resistance, but, in turn they have a low conduction coefficient. In the following section, microbolometer are analyzed with all these three types of intermediate layers.

Because more of temperature variation occurs within arms sections, material type of intermediate layer has a considerable effect on microbolometer performance. In the case of poly-silicon as intermediate layer, temperature difference reaches 301.01 from 293.15 Kelvin

degree that is more than temperature difference of metal case. As nitride is used as intermediate layer, this value increase noticeably and reaches 345.52 from 293.15 Kelvin degree. Therefore, one could conclude that material of intermediate layer has a considerable effect on microbolometer behavior and, consequently, its performance.

The values of responsivity and detectivity variations for all three cases are compared with each other and listed in table 2. Nitride layer has the highest amount of these parameters.

Table 2. Comparison between the values of obtained responsivity and detectivity.

Intermediate Layers	D*(cmH ^{1/2} /W)	R (V/W)	Thermal conduction coefficient (W/m.K)
Metal	1/7571×10 ⁹	3833/6	181
Poly-silicon	2/1861×10 ⁹	5934	18
Nitride	5/1334×10 ⁹	32721	1/5

According to the obtained results, for better investigating the effect of material type of intermediate layer on microbolometer performance, following graph has been depicted. Based on the mentioned graph, one could observed that applying materials with thermal conduction coefficient less than 10 W/m.K improves microbolometer performance, considerably.

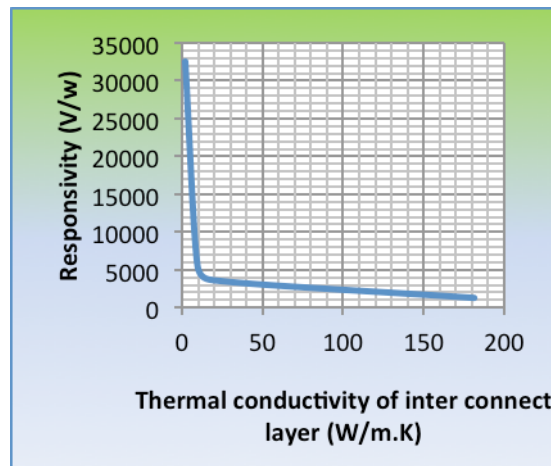


Figure 2. Responsivity curve in terms of thermal conduction of intermediate layer.

Another material that has been used as active element in spite of n-well is platinum, which has a very low thermal resistance coefficient. Platinum is used when long-term stability is needed. Analysis results are shown in figure 3.

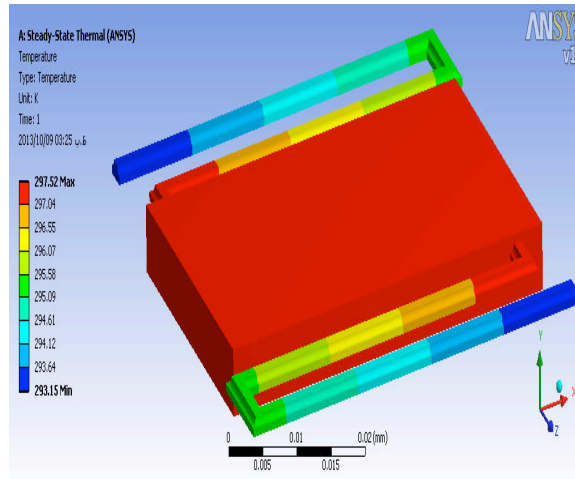


Figure 3. Simulation results of designed model with platinum.

As could be observed from simulation, temperature variation is reached from 293.15 to 297.52 degree of Kelvin. Responsivity and detectivity values are calculated by this temperature difference that are improved less than previous models. Therefore, one could conclude from this study that platinum layer play a little role on the improving microbolometer behavior in comparison to n-well layer.

5. CONCLUSION

In this paper, a new microbolometer structure that is obtained from any cmos standard process has been reported. In this structure, n-well layer has been used as active element that its thermal resistivity coefficient was around 0.05 % k. Three different material with various thermal conduction coefficient have been suggested for intermediate layer on supporting arm, in which, based on analysis results of ANSYS software, it was observed that using material with thermal conduction coefficient less than 10 W/m.K will improve performance of microbolometer, considerably. Nitride with its low thermal conduction coefficient has more influence on microbolometer performance in comparison with poly-silicon and metals.

REFERENCES

- [1] Gordley. Lany," A Space Instrument Application Of An Uncooled Infrared Microbolometer Array", IEEE,GATS Inc., Newport News, VA 23606,8, 2 000.
- [2] Niklaus. Frank," MEMS-Based Uncooled Infrared Bolometer Arrays – A Review", MEMS/MOEMS Technologies and Applications III, SPIE VOL 6836, 68360D,15,2007.
- [3] Song. Woo-Bin," Design and characterization of adaptive
- [4] Microbolometers" Micromech. Microeng. 16 IOP Publishing Ltd Printed in the UK 1073-1079,7,2006.
- [5] Tezcan. Deniz Sabuncuoglu," An Uncooled Microbolometer Infrader Detector in any standard Cmos technology ", The 10th Int. Conf. on Solid-State Sensors&Actuators (TRANSDUCERS'99), pp. 610-613, 4, Sendai, Japan, June 7-10, 1999.
- [6] Tezcan. Deniz Sabuncuoglu," A Low-Cost Uncooled Infrared Microbolometer Detector in Standard CMOS Technology", IEEE Transactions on electron devices, VOL. 50, NO. 2,9, FEBRUARY 2003.
- [7] Wang. Li-Xia,"Preparation of VO₂ Microbolometer for CO₂ gas Detection", IEEE,College of Science, Nanjing University of Posts and Telecommunications, Nanjing, China, 210046,4, 2010.