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Optimization of an infrared thermal mems-based microbolometer detector

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Abstract. This paper present a new n-well microbolometer structure (silicon well or n-type impurity) as active element that is obtained from every cmos standard process. Results of manufactured chips show that n-well layer have a TCR value about 0.5%/k. due to the heat flux into the microbolometer, temperature variation occurs within it that, as a consequence, leads to resistivity variation. Because microbolometer performance depends on the structure dimension, it has been tried to obtain optimized structure, precisely, by varying thermal simulation dimensions in ANSYS software. As a result, maximum specific detectivity has been determined equals to 1.391×10^9 cmHz$^{1/2}$/W and responsivity as 3933.6 V/W. This economic method with appropriate performance is suitable for producing large focal plane arrays for uncooled infrared imaging.

Keywords: Infrared beam, microbolometer, specific detectivity, responsivity

1. INTRODUCTION

Almost, in all of scientific experiments detectors plays an important role and the quality of experiments depend on the parameters of applied detectors such as detectivity rate, noise, least detectable signal and so on. Regarding advantages such as light weight, low cost, low power and large spectrum response and long-term application, one of the best way for uncooled infrared imaging is microbolometer structure. In this method, infrared beam is used for increase of body temperature and, as a consequence, leads to the variation of resistivity [1,4].

Various materials have been used for microbolometer. 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. The main disadvantage of VO_x is that is not a standard material in IC manufacturing processes. Another microbolometer material that is consistent with IC (sic) is amorphous silicon carbide. Its TCR value is 4-6 %/k, but this material needs a high thermal durability to achieve microstructure stability which is difficult to integrate with a cmos process for implementing integration process of integrated circuits.

Another material for microbolometer that is consistent with IC is poly SiGe with TCR value of approximately 2-3%/k. Another alternative with low temperature and consistent with IC is metallic layers e.g. platinum. The resistivity of platinum vary with temperature. Thin layer of platinum has a good linear property, but platinum has a low TCR value that generally limit its applications. In this paper, n-well is used as active element which is a silicon well with n-type impurity that has a TCR value of approximately 0.5 – 0.75 %/k that is sufficient for infrared

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applications. N-well microbolometer provides easily implementation of focal plane arrays with suitable performance and low cost for infrared imaging.

2. MAIN MICROBOLOMETER PARAMETERS

Every microbolometer includes a series of structural and imposed parameters that each of them plays an essential role in microbolometer performance. The most important characteristic of a microbolometer is its specific detectivity rate that is defined as follows:

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

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:

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

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:

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

where;

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

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

3. STRUCTURE OF N-WELL MICROBOLOMETER

In figure 1, top view of one n-well microbolometer pixel has been shown. Microbolometer dimensions is 50×50 μm. In this type of microbolometer, n-well layer is surrounded by an empty region that allow the underlying silicon disk has been eroded. There is a metal-oxide layer on the n-well layer that absorbs radiation power. In addition, there are two supporting arms in both sides of n-well layer. Electrical contact is possible through intermediate layer.

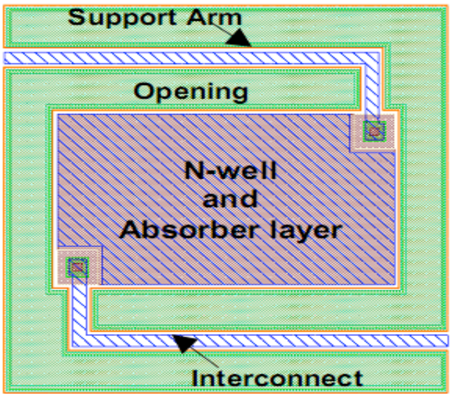

Figure 1. Top view of one n-well microbolometer pixel [3].

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 [3].

4. EVALUATION AND OPTIMIZATION 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 [5].

Characteristics and required conditions for analysis is listed in table 1.

Table 1. Microbolometer characteristics for ANSYS analysis.

Characteristic	**value**
Absorbing layer	0.05 mm×0.03 mm
Cross section dimension of supporting arm	0.0025 mm×0.005 mm
Length of supporting arm	0.05 mm
Width distance between arm and absorbing	0.001 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	0.62 K

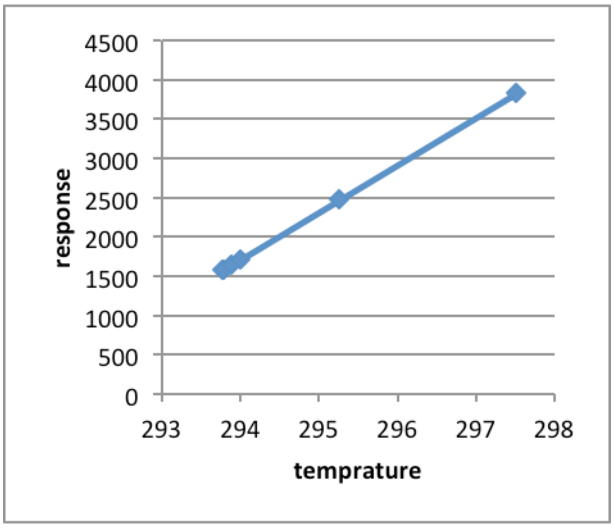

Figure 4. Responsivity behavior with respect to temperature.

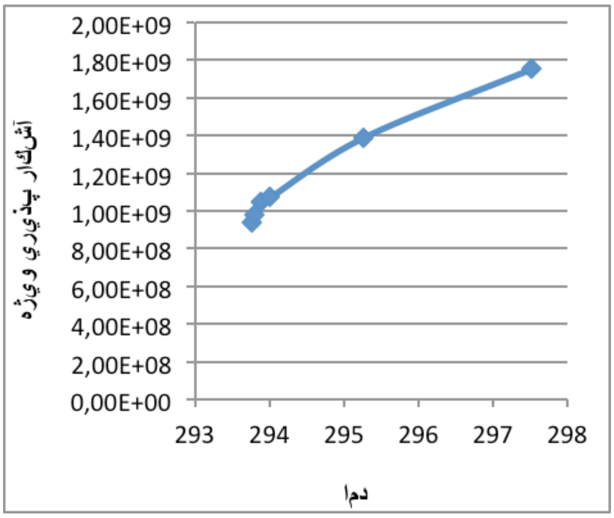

Figure 5. Specific detectivity with respect to temperature.

As could be observed from figures, with the increase of temperature responsivity and specific detectivity will be increased that leads to improvement of microbolometer performance.

5. CONCLUSION

In this paper, a new microbolometer structure that is developed in every cmos process has been reported. In this structure, an n-well layer with resistivity temperature coefficient of 0.5% /k has been used as active element. Because n-well performance is affected by dimensional design parameters, length of arms, width distance between arm and absorbing, cross section and absorbing have been increased. Thermal simulation to obtain optimized structure conducted in ANSYS software, precisely, and maximum specific detectivity and responsivity has been determined. Simulation results show that detector has a comparable performance with respect to other microbolometers.

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