STUDYING THE INFLUENCE OF MICROBOLOMETER STRUCTURE AND GEOMETRY ON THE PARAMETERS OF INFRARED DETECTORS

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I. INTRODUCTION

The fields of application of thermal detectors are constantly expanding, for example in areas such as security, surveillance, fire fighting, biomedicine. A microbolometer based on a microbridge structure has an advantage over the other capabilities of IR detectors: it has low power, low cost, and can operate at room temperature [1-3]. The main requirements for thermosensitive materials used in microbolometers are high TCR (α), moderate resistivity, low noise, and compatibility with silicon (Si) integrated circuit (IC) technology. The most common materials are VOx, amorphous and polycrystalline silicon, and some metals [4-6]. The use of amorphous Si makes it possible to reduce the pixel size [7]. It is necessary that the sensing element of the IR sensor is thermally insulated. Various manufacturing processes have been proposed to reduce heat loss. The best thermal insulation and lowest thermal performance are obtained in microelectromechanical systems (MEMS) designs, which are used in Infrared Focal Plane Arrays (IRFPA) systems. Micromachining techniques are used to suspend the thermosensitive member of the substrate in a jumper shape to minimize heat loss due to conduction through the substrate. The structure and geometrical size affects the thermal performance of bolometer structures. In addition, the small pixel size requires a more complex mechanical and electrical design. In this article, special attention is paid to the study of the design parameters of the microbolometer, as well as the procedure for its manufacture.

II. RESULTS

The standard design of a microbolometer consists of a single suspended multilayer membrane and long support legs [8]. The membrane includes films made of dielectric and thermosensitive material, conductive and absorbing layers. The main mechanism for heat transfer is thermal conductivity from the temperature-sensitive material to the substrate through the support structure, which performs three functions: mechanical, conductive, and heat-conductive.

The paper considers several design solutions of a microbolometer, which differ in the suspension width (2w for structure 1 and w for structure 2), the number of thin TiN films (one for type 1 and two for type 2). Each structure is considered in three versions, differing in size: 37.5 μm (a), 25 μm (b) and 12.5 μm (c). Amorphous silicon was chosen as a heat-sensitive material. Instrument structure 2 of type 2b is shown in Figure 1.

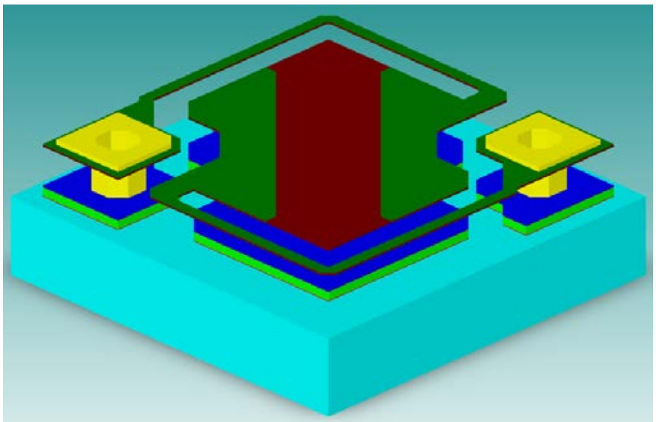

Figure 1. Device structure 2 (type 2b) of the microbolometer

Table 1 shows the main parameters of the structures under consideration. Thermal conductivity G is determined by means of stationary thermal analysis. The time constant τ is obtained from a temperature response curve fit (transient thermal analysis). Specific heat C was calculated from the known values of G and τ. The resistance value is determined from the results of stationary electrothermal analysis at a reference temperature of 300 K (with a voltage between the contacts of 0.1 V).

Table 1. Results of modeling the operational characteristics of microbolometer device structures

Design Parameter	Value					
	Structure 1					
	a		b		c	
	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Thermal conductance G, (W/K) $\times 10^{-8}$	5.320	9.300	5.310	9.266	5.312	9.265
Thermal time constant τ, ms	3.240	2.130	1.382	0.890	0.798	0.529
Specific Heat C, (J/K) $\times 10^{-11}$	17.24	19.80	7.33	8.25	4.24	4.90
Resistance 300K R, MOhms	9.140	9.108	9.162	9.074	9.186	9.108
Thermal coefficient of resistance TCR, 1/K	-0.0269	-0.0268	-0.0273	-0.0267	-0.0269	-0.0267
Maximum deflection 300K MD, um	2.400	0.019	1.120	0.090	0.650	0.006
Fill factor of the sensor β	0.61	0.61	0.66	0.66	0.61	0.61
Responsivity R_v, (V/W) $\times 10^{6}$	2.165	1.337	2.710	1.530	2.520	1.430
Design Parameter	Structure 2					
	a		b		c	
	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Thermal conductance G, (W/K) $\times 10^{-8}$	2.560	4.494	2.560	4.494	2.560	4.491
Thermal time constant τ, ms	5.660	3.650	2.458	1.565	1.590	0.900
Specific Heat C, (J/K) $\times 10^{-11}$	14.490	16.388	6.290	7.033	4.070	4.042
Resistance 300K R, MOhms	9.140	9.100	9.163	9.103	9.207	9.107
Thermal coefficient of resistance TCR, 1/K	-0.028	-0.027	-0.028	-0.027	-0.028	-0.028
Maximum deflection 300K MD, um	2.300	0.019	1.068	0.009	0.615	0.057
Fill factor of the sensor β	0.517	0.517	0.560	0.560	0.517	0.517
Responsivity R_v, (V/W) $\times 10^{6}$	3.148	2.096	4.530	2.640	4.488	2.595

III. CONCLUSIONS

The influence of the shape and width of the support structure of the device on the operational characteristics of thermal detectors of the bolometric type has been studied. The thermal conductivity of the considered design solutions is relatively low, especially for structure 2 (due to the doubled shoulder width). Type 1 have a higher thermal conductivity than type 2 for the same structure. Moreover, for them the maximum deflection is greater from above, since they are only one film TiN. Structure 2 has the best sensitivity R_v. Summarizing all the parameters, it is shown that the microbolometer 2b of structure 2 has the best characteristics.

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