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The new approaches in a process engineering high power microwaves diodes millimeter wave band*

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Abstract: The reachings in the field of deriving modern materials of a microelectronics engineering are especially effective, when the process engineering of manufacture of the concrete device allows maximum to realize the resources, included in active structure.

In the report the outcomes of results on a considerable diminution of thermal restrictions generating impatt diodes millimeter (mm) wave band are submitted with the purpose of improving exit pupils and reliability. The complex of original design technological receptions has allowed to solve a problem of making multimesa wave band structures, in which the thermal resistance is possible to reduce in inverse proportion $\sqrt{n}$, where n-number of mesa structures. The sectional process engineering has general purpose character and is applicable to the most composite materials in particular to heterostrucructures and all types of made on their bases microwaves diodes containing a mesa structure. The results are illustrated on silicon double drift six mesa structure 5 mm wave band for which the level of an output continuous power 1.04 watts on frequency 65.9 GH_2 is obtained. Thus p-n junction temperature did not exceed 220℃ usual copper heatsink also was utillized. The electronic snapshots and outcomes of investigation of thermal fields silicon mesa diodes of a various configuration are reduced: to six mesa, eight mesa, ring.

Singularity of a sectional process engineering are higher specific mechanical loadings at assembly of devices, therefore with the purpose of a raise of reliability and percent of an exit of suitable devices designed and the procedure permitting to inspect on starting plates amplitude and a strain gradient in active region is tested X-ray diffraction method that is especially important for heterostructure mesa diodes.

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The reaching in the field of deriving modern materials of a microelectronics engineering are especially effective when the process engineering of manufacture of the concrete device allows maximum to realize the resources included in active structure. All limiting exit parameters for Si and GaAs millimeter—wave diodes such as IMPATT diodes and Gunn diodes are achieved at the expense of use in a construction of the device diamond heat sink. This construction is base on these devices and on a basis of more perfect materials.

At the same time on frequencies more than 60 GHz the scoring in use of diamond heat sink begins to be reduced because of a diminution of sizes mesa structure less than 30—40 microns in a diameter. The further effective drop of thermal resistance is possible only at the expense of a modification of geometry of a crystal

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and collimating to it of the shape of structure with a strongly developed periphery that increments heat output in a side direction. It allows taking the most of possibilities of a material of heat sink. However making of such structures is strongly hampered by extremely small working dimensions mesastructure and singularities of their installation on heat sink.

The outcomes of examinations directional on development of a process engineering of multi mesa crystals manufacture are below submitted in which the thermal resistance decreases in inverse proportion $\sqrt{n}$, where n number of mesa structures. The sectional process engineering has general purpose character and is applicable to the most composite materials in particular to heterostructures and all types of microwaves diodes, made on their bases containing a mesa structure.

The complex of original design-technological receptions was testing on silicon IMPATT diodes millimeter-wave. As experimental is model were are implemented silicon IMPATT diodes shaped of fissile structure as a 6-mesa structures ring, 8-mesa structures ring. In Fig. 1 the fragment of 8-mesa IMPATT diode at a stage of the representation on a starting plate of working geometry for operation in 5 mm wave band is submitted.

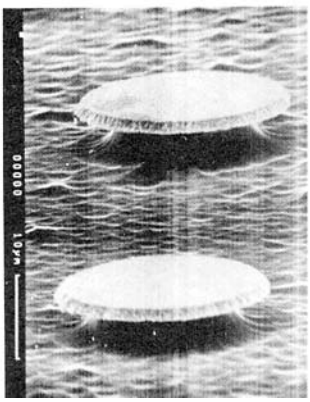

Fig. 1

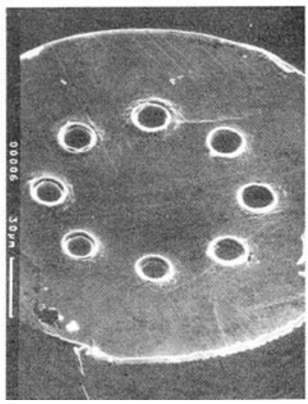

Fig. 2

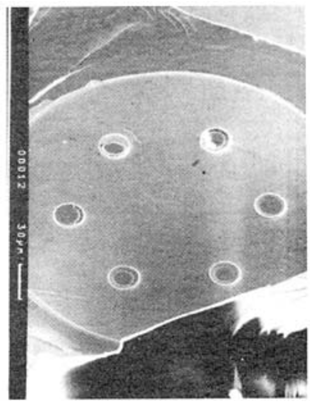

Fig. 3

Diameter of silicon simple structure at the foundation p-n junction is about 16 microns at height of a mesa structure about 4 microns. The aggregate square p-n of passages makes all of eight mesa structures 1.6×10^{-5} cm^2 that corresponds to a diameter one mesa of structure about 45 microns. In Fig. 2 the structure after its installation on gold heat sink is submitted same 8-mesa structure. For comparison silicon IMPATT diode of firm NEC ND8L60W-1T 5 mm wave band on diamond heat sink have thermal resistance 40℃/W, while the structure, submitted in Fig. 1 allows to receive on usual gold heat sink 20℃/W. The combination of the indicated structure with diamond heat sink would allow reducing thermal resistance twice.

The output microwaves parameters were obtained for silicon double-drift p^+pnn^+ 6-mesa structure of 5 mm wave band which are reduced in the Table 1.

In this table ΔT_1-overheating temperature of p-n junction in a case of absence of microwave of generation, ΔT_2-overheating temperature of p-n junction in a case that the part of an entering power does not dissipate as heat and is transformed to output power of a microwave.

In Fig. 3 this structure after its installation on gold heat sink is submitted.

Singularity of a sectional process engineering are higher specific mechanical loadings at assembly of devices therefore with the purpose of a raise of reliability and percent of an exit of suitable devices, designed and the procedure is tested X-ray diffractometry method[2] permitting to control on starting plates the strain amplitude and strain gradient that is especially important for mesa diodes on a basis of heterostructure.

Table 1

Break down voltage U_{br}, V	Total capacitance at V=0, C(0) (pF)	Heat resistance R_T, ℃/W	Diod current I, mA	CW Power outputs available P_{out}, mW	Generation frequency f, GHz	ΔT_1, ℃	ΔT_2, ℃	Effici-ency, %
23.7	1.4	21	200	450	65.8	124	114	7.67
			290	850	65.3	191	174	8.5
			325	1040	65.9	218	196	10
23.7	1.25	22	175	340	66.8	112	104	6.7
			250	720	—	170	155	9.3
			300	980	68.3	212	190	9.8

In the Table 2 the outcomes on percent of an exit suitable 8-structure IMPATT p^+nn^+ and p^+pnn^+ such diodes as with different strain gradient $\Delta\varepsilon/h$, strain amplitude ε_0 and thickness of a film h on operations assembly and electric thermal training are reduced.

Table 2

Samples	$\Delta\varepsilon/h$, 10^{-4} micron^{-1}	ε_0, 10^{-4}	h, micron	Percent of an exit of suitable deviceses	
				After assembly	After testing
1	-33.9	-12.0	0.35	48	23
p^+nn^+	-34.4	-11.9	0.35	50	18
2	-26.13	-14.4	0.55	34	60
p^+nn^+	-25.9	-14.0	0.54	36	57
3	-65.2	-9.78	0.15	73	23
p^+pnn^+	-96.4	-9.64	0.10	74	20

Samples with major values of a strain in p^+ layer give smaller percent of an exit on assembly operation. Samples with a major value of strain gradient give smaller percent of an exit suitable on operation electric thermal training. Thus using X-ray diffraction method has shown correlation between strain both strain gradient and percent of an exit of suitable devices. The utilized X-ray diffraction analysis has allowed in a result on the one hand to correct design sizes installed at assembly of the device of crystals on the other hand has reduced in the particular technological requirements to a class of a surface of heat sink. In a result it was possible to realize performances multi mesa IMPATT of a millimeter wave band reduced in the Table 1 at the greater reliability of operation of devices and their greater percent of an exit.

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