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Integrated TRAPATT Diode Arrays

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***Abstract*—This short paper is a description of the technique used to monolithically interconnect TRAPATT diodes in an array—resulting in a diode having low inductance interconnection and integrated heat capacitance which is necessary for long pulsewidths. For given power dissipation density and pulse length, the transient temperature rise in the diode decreases with the diameter. The reduction in diode diameter, however, leads to reduced power output. To take advantage of the reduction in temperature rise of small-size diodes while maintaining a large power output, a multiple-diode structure, monolithically interconnected, was fabricated.**

Pulsewidth operation of 50 μs has been achieved at a dissipation power density as high as 200 kW/cm², whereas the dissipation density must be reduced to 100 kW/cm² for the same total-area single-disk diode to operate reliably at 50 μs.

DIODE CONSIDERATIONS

The temperature rise of the TRAPATT diodes is a critical factor in limiting the device performance because it can ultimately lead to device failure. The dissipated energy per pulse, as well as the average power dissipation, are among the highest values required of any solid-state device. Therefore, it is necessary to give careful consideration to the dynamic thermal conditions in the diodes, and to the development of thermal design criteria that will lead to satisfactory performance.

The diodes in the array were interconnected both by utilizing monolithically connected metallized bridges and by soldering a piece of copper on top of the diodes. The additional copper mass acts as a heat capacitor, temporarily absorbing heat transients and thus extending the permissible operational pulsewidth. The diameter of each diode is sufficiently small to provide thermal spreading during the required pulse length, and, thus, the temperature rise during the pulse is reduced. The spacing between the diodes is sufficiently large to prevent thermal overlap between adjacent elements.

INTEGRATED DIODE ARRAY AND METALLIZED AIR BRIDGE

The diode array is fabricated by applying a dot pattern mark on a photoresist covered wafer, followed by a mesa etching. The process results in an array of diodes on a single integrated heat sink. This integrated heat sink (having diode arrays) is mounted on a microstrip line package, and then a gold-plated copper disk is soldered on the diodes' tops for interconnection. Later, a metallized air bridging technique [1], [2] is used to interconnect the "individual diode" mesas. The metallized air bridge provides, in addition to low inductance interconnection, an integrated heat capacitance which is necessary for long pulsewidth (50–100 μs) applications, such as in pulsed amplifiers for phased-array radar systems.

The processing steps applied to TRAPATT arrays are similar to the technique described by Basseches and Pfahnl [1] for interconnections on passive substrates. The major difference is that active semiconductor silicon mesas of small sizes, rather than large metal circuit patterns, are formed and interconnected. This semiconductor material must be protected amidst the large contour topography of the mesas, leading to a new process.

Detailed steps of this process are shown in Fig. 1 and are described as follows.

1) Batch process diodes using the standard mesa techniques.
2) Test all devices.
3) Apply positive photoresist, expose, and develop using a mask of array dots that are slightly smaller than diodes. This step serves two purposes: a) to prevent copper plating on top of the diode; and b) to protect the diode junction while plating.
4) Copper plate between the diodes and between arrays to a height slightly above mesa height.
5) Remove the photoresist above each diode.
6) Reapply the photoresist, expose, and develop using a connection pattern mask.
7) Gold plate to a thickness of 2 mils.
8) Remove the photoresist.
9) Remove the copper.
10) Remove the photoresist around mesa body.
11) Test.

Scanning electron micrographs (SEM's) of interconnected seven-diode arrays are shown in Fig. 2, and their I-V characteristics are shown in Fig. 3. The interconnection of the arrays was checked by comparing the junction capacity of the array with the junction capacity of single diodes within the array.

DIODE PERFORMANCE

The multiple diodes have been tested in S-band TRAPATT amplifier circuits. The results of the tests are summarized in Table I.

Seven-diode arrays made from a p-type wafer operated at an efficiency of 26.5 percent, 70-W output power, and 5.5-dB gain at S band in a coupled-bar circuit [4]. The 85-W output power at 50-μs pulsewidth has been achieved with a 19-diode array made from a double-diffused wafer [5] in a stagger-tuned microstrip line amplifier circuit [6]. The dissipation power density of the ordinary disk diode has to be controlled to be less than 100 kW/cm² to operate at 50-μs pulsewidth, but the array diode could dissipate at as high as 200 kW/cm² while operating at 50-μs pulsewidth. This indicates that the array structure is superior to the ordinary disk structure in power-handling capabilities.

Two 19-diode arrays made from a p-type wafer were mounted in series on a microstrip line package. Array diodes in series were operated in a stagger-tuned microstrip line circuit and demonstrated a 360-MHz bandwidth with an output power of 130 W (Fig. 4). This result has been obtained by an input level profiling technique in which the input RF power is adjusted as the frequency is varied to give a detected output waveform with no observable noise. The maximum gain was 6.5 dB and the maximum efficiency was 14.2 percent.

CONCLUSIONS

TRAPATT devices show great potential in the area of pulsed amplifiers for phased-array radar systems.

To achieve simultaneous high peak powers at high-duty cycle and long pulsewidth, special attention must be paid to the design

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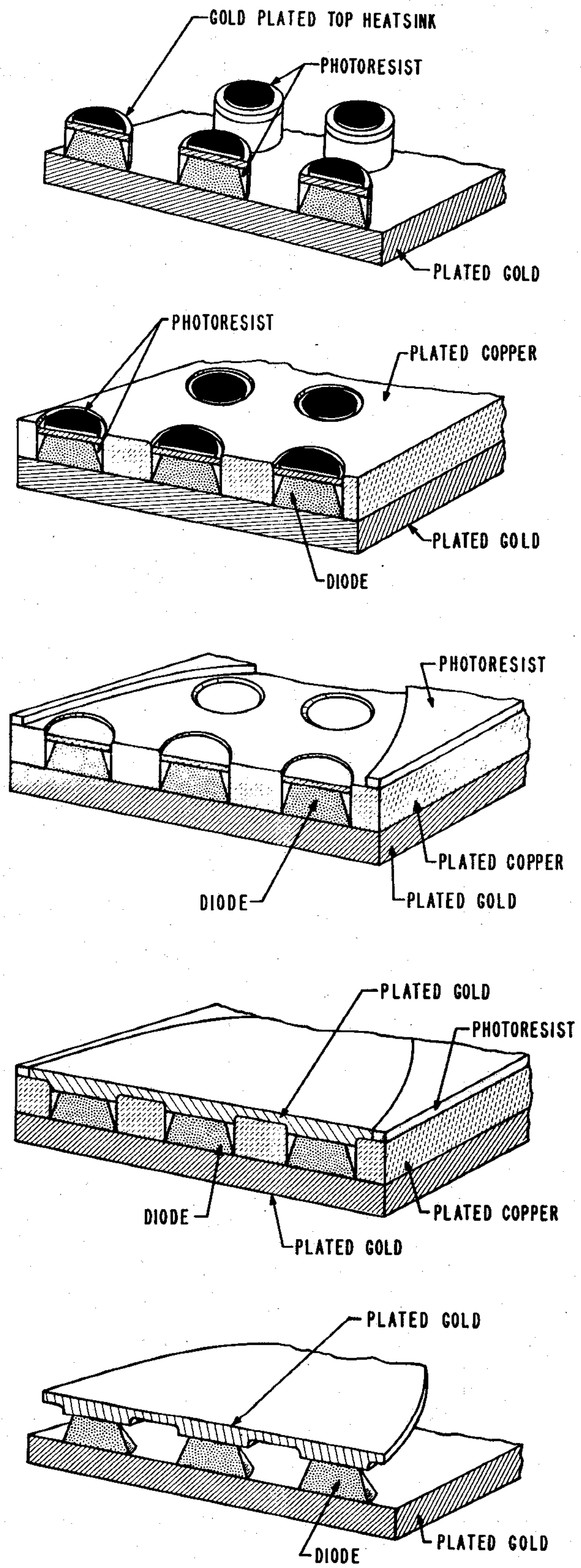

Fig. 1. TRAPATT diode process sequence.

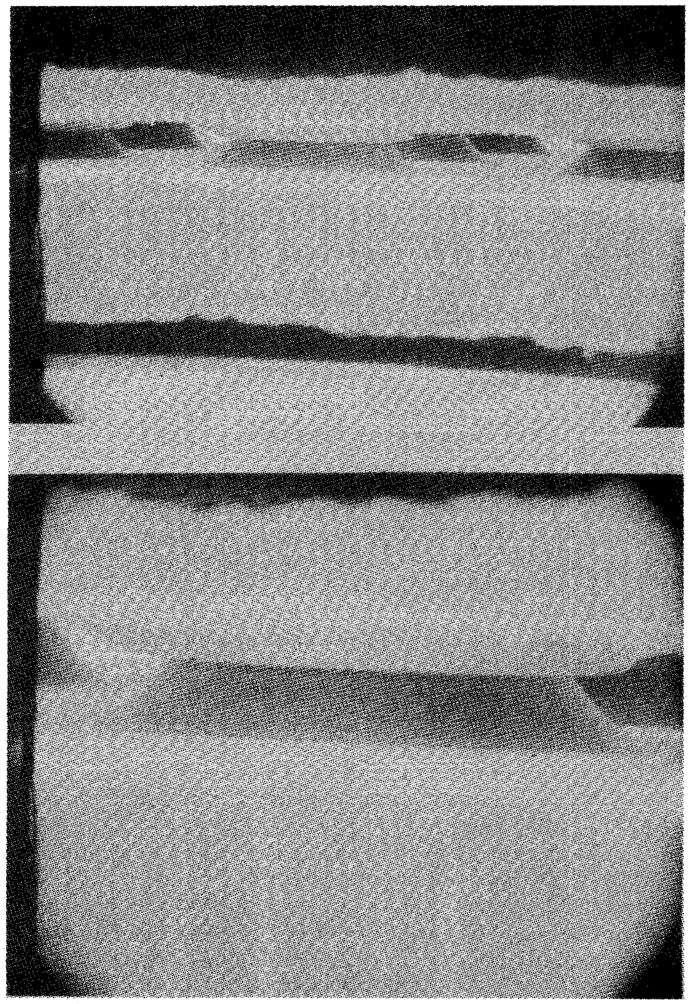

Fig. 2. SEM's of interconnected seven-diode arrays.

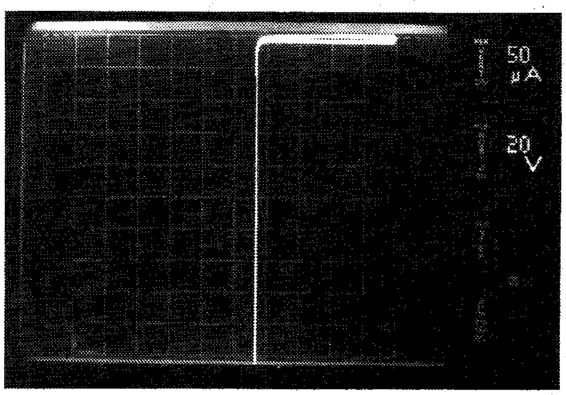

Fig. 3. Seven-diode array I-V characteristics.

of the diode, and careful consideration given to the dynamic thermal conditions to which the diode is subjected.

The multicircular dot approach is utilized since thermal spreading, especially in the case of transient thermal spreading, occurs at the diode edge (the greater the thermal spreading, the lower the temperature of operation). Therefore, an array of 20 0.006-in dots, for example, has almost twice the periphery, or edge, of a 0.006-in stripe of equivalent area, and its temperature of operation will be significantly lower.

The monolithically interconnected bridges, which act as heat capacitors, eliminate the usual solder interface between the top gold contact of the diodes and the piece of copper which is to act as a heat capacitor. This reduces diode fabrication time and results in increased yield (equivalent to diode yield).

A pulsewidth of 50 μs has been achieved at a dissipation power density as high as 200 kW/cm^2, whereas the dissipation density must be reduced to 100 kW/cm^2 for the same total-area single diode at the same pulsewidth.

TABLE I
PERFORMANCE OF ARRAY DIODES

Circuit Type	Diode	Type	Peak Output Power (W)	Frequency (GHz) (Power Variation)	Max. Gain (dB)	Max. Efficiency (%)	Power Density (kW/cm^2)	Duty Cycle (%)	Pulse-width (μs)
Coupled-bar	7-array[a] p-type	KR5B	70	3.05 - 3.15 (3 dB)	5.5	26.5	155	-	0.5
Stagger-tuned	19-array[b] double-diffused	KK265	150	3.02 - 3.07	7.5	9.4	179	0.05	10
	19-array[b] double-diffused	KK265	85	3	4.5	10.9	200	1	50
	19-array[b] p-type	AK4B 2 in series	130	2.875 - 3.235 (1.15 dB) profiling	6.5	14.2	115	0.02	5
	19-array[b] p-type		120	2.95	7.2	19.2	155	0.02	10
	19-array[b] p-type		110	2.95	6.8	15.7	163	1	50

[a] Utilizing monolithically interconnected bridges.
[b] Soldering copper on top of diodes.

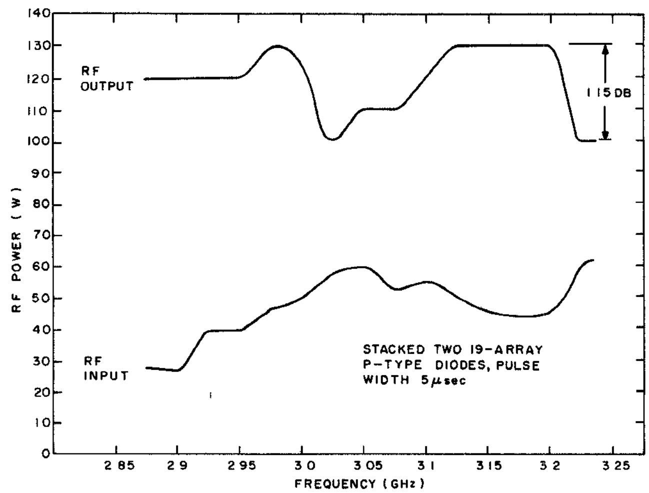

Fig. 4. Power output versus frequency from two stacked 19-diode arrays (profiling technique).

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Commercial Glow Discharge Tubes as Detectors of *X*-Band Radiation

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***Abstract*—A survey of the detection properties of various commercial glow discharge tubes to *X*-band radiation is presented, and comparisons are made with typical sensitivities of diode detectors.**

Although glow discharge detection of microwave radiation has been known since at least 1952 [1], Farhat [2] was probably the first to use very inexpensive commercial indicator lamps in this

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