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GaAs DDR (Double-Drift-Region) IMPATT Diodes Made by A Successive Liquid Phase Epitaxy

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Recently GaAs IMPATT diodes are being evaluated for their superior output power, efficiency and noise performance in comparison with Si IMPATT diodes[1,2]. In 1970, D.L.Scharfetter et al. proposed a double-drift-region (DDR) IMPATT structure in which both hole and electron were utilized generating microwave power so that excellent performance could be expected. And T.E.Seidel et al. realized a Si DDR IMPATT diode employing ion implantation and showed that the DDR IMPATT diode is superior to a usual Si IMPATT diode in most respects. Therefore, GaAs DDR IMPATT diodes are supposed to be a promising microwave source, some trials have been rèported elsewhere[3] but they have not yet reported the power generation using this structure. In this work, we tried to make GaAs DDR IMPATT structure by liquid phase epitaxy and succeeded in generating microwave power.

In our experiment, a four-layer structure was grown on (100) oriented n^+-GaAs substrates by using a successive liquid phase epitaxy technique similar to the one reported before.[4] The liquid phase epitaxy was carried out using the sliding graphite boat with four different Ga-rich solutions, three of which were used to grow the n-drift, p-drift and p^+-contacting regions, and the remainder of which was used to wash the surface of the epitaxial layer before the growth of p-drift region. By introducing the washing process, the contamination caused by the remainning solution on the previously grown epitaxial layer could be decreased.Therefore, the carrier concentration of each layer could be controlled in the region of 10^{15}-$10^{16}cm^{-3}$ by the amount of Sn or Ge present in Ga solution. The thickness of each layer was controlled by regulating the time of epitaxial growth, and the layers are quite uniform in thickness.The carrier concentration profile of the n-drift region was measured by the differential capacitance method and the carrier concentration profile of the p-drift region was calculated using the carrier concentration profile of the n-region and effective carrier concentration profile of the diodes. Fig.1 showes the typical carrier concentration profile of a p^+-p-n-n^+ structure. From this Figure, it is seen that the carrier concentration of n- and p-drift region is quite uniform and that the abrupt junction is obtained.

After the epitaxial growth, the substrate was lapped and etched down to a final wafer thickness of about 25μm, and contacting metales were evaporated onto the both wafer surfaces. The wafer was then cleaved into small dice, which were alloyed onto Au-plated Cu studs.

Typical diodes had a breakdown voltage of 36-38V and a junction area of $2\text{-}6\times10^{-5}cm^2$, and the reverse currents were about $10^{-10}A/cm^2$ at -10V. An end hat cavity was used to measure the RF characteristics of the diodes, one of which is shown in Fig.2 where the characteristics of a GaAs SDR diode is also shown. From Fig.2 it is seen that the diode obtained in this work operates at a lower current density than the SDR diode. And the breakdown voltage of this diode was about two times as large as that of the SDR diode with the same operating frequency. From these results, this diode with the $p^+\text{-}p\text{-}n\text{-}n^+$ structure is supposed to operate as the GaAs DDR IMPATT diode.

As the large signal analysis of the GaAs DDR IMPATT diode predicted a maximum efficiency of 20% at 36GHz,[5] the degradation of the efficiency and the frequency in the experiment was supposed to be mainly due to the residual resistance of the substrate and the unswept regions.

References

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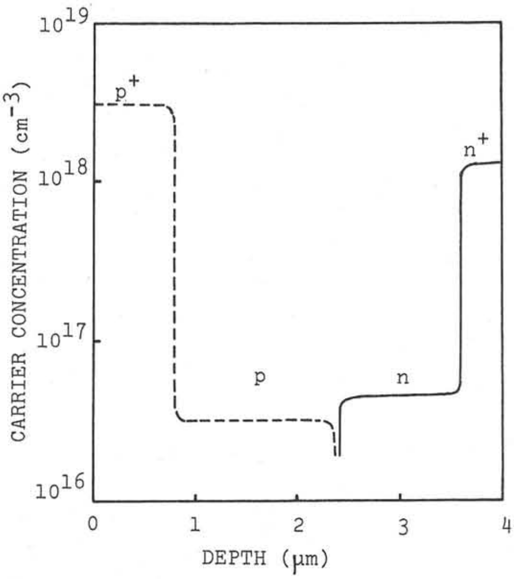

Fig.1 Carrier concentration profile of GaAs DDR IMPATT diode.

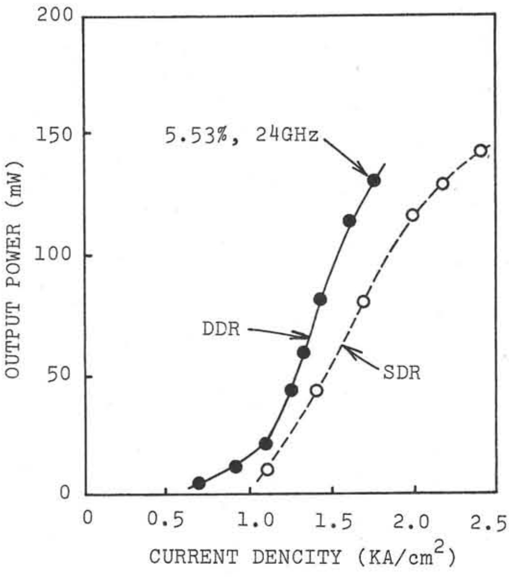

Fig.2 RF characteristics of GaAs DDR IMPATT diode.