Monolithic Implementation of a Planar Gunn Diode and a pHEMT.

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Planar Gunn diodes initially demonstrated oscillations above 100 GHz, displaying that these devices can be the millimeter-wave sources in monolithic microwave integrated circuits (MMICs) [1]. After the introduction of extra delta-doping layers and $In_{0.23}Ga_{0.77}As$ channel layers, the generated power was doubled [2] and the maximum oscillation frequency reached to 116 GHz [3]. The maximum frequency of oscillations was recently increased to 164 GHz after the introduction of $In_{0.53}Ga_{0.47}As$ channel layers [4].

The implementation of the Gunn diode alongside a high-electron mobility transistor (HEMT) could provide a very significant potential for the development of the oscillator. Transistor-based amplifiers could easily be integrated with the diode for the signal reinforcement, while mixer circuits could be used for the extraction of high order products. The two active devices have never previously been integrated on the same substrate as the conventional Gunn diode is typically a vertical transport device where the HEMT is a lateral transport device. In this work, we present the realisation of a planar Gunn diode and a HEMT on the same chip. The AlGaAs/GaAs - based layer structure was designed for the implementation of pHEMTs, including an $In_{0.2}Ga_{0.8}As$ channel layer (Figure 1). Spectrum analyzer measurements prove the previously reported Gunn instabilities on HEMT wafers [5].

The fabrication of the two devices is simplified as they use the same active layers. Therefore, the Gunn diode shares the most fabrication steps with the pHEMT. A bi-layer of 12 % and 2.5 % PMMA was used for the definition of the Ohmic contacts mask. A 14 nm Au/14 nm Ge/14 nm Au/11 nm Ni/70 nm Au metal stack was evaporated afterwards, which is commonly used for the formation of low resistive Ohmic contacts on a highly doped GaAs cap layer. The contacts were annealed at 400 ºC for 60 s and the resulted electrodes resistivity was 0.32 Ω.mm. A PMMA mask layer was baked at 180 ºC in a conventional oven for two hours in order to protect the mesa areas of the devices. The active areas where isolated afterwards, using a 10:1 - $C_6H_8O_7$:H_2O_2 citric acid wet etching solution. A 70 nm T-gate technology was incorporated using two 4 % PMMA layers at the bottom and a more sensitive layer of 12 % PMMA on the top. The resist pile was initially exposed to a low-dose electron beam for the definition of the head, where a second high-dose exposure was used for the foot area. The resist development was followed by the recess etching. A succinic acid wet etching solution with controlled PH at 5.9 was applied for 20 s. The fabrication of the T-gate was completed after the evaporation of a 15 nm Ti/15 nm Pt/400 nm Au metal stack. A 20 nm Ti/500 nm Au metal bi-layer was evaporated afterwards for the formation of the CPW pads of the devices. The final stage involves the reduction of the cap layer between the anode and the cathode of the Gunn diode. This was carefully reduced using the same succinic acid wet etching solution described before. In this way, the diodes were protected from a possible burn out that is caused by the high electric field appearing near the electrodes.

Fabricated two-finger pHMETs with 12 μm width presented a maximum drain current of 780 mA/mm. The maximum transconductance was equal to 780 mS/mm after applying a gate bias of 250 mV and 1.0 V drain bias. The RF performance of the devices is illustrated in Figure 2(a) where the cut-off frequency is equal to approximately 90 GHz and the maximum frequency of oscillation is equal to 200 GHz. Figure 2(b) presents the measured spectrum of a 60 μm wide planar Gunn diode with 1.3 μm anode to cathode separation. The diode generates oscillations at 87.6 GHz when the maximum output power is equal to -40 dBm.

In conclusion, the introduction of extra delta-doping layers could significantly enhance the diode performance in the future. The current results are very promising, considering the relatively high resistivity of the Ohmic contacts. Also, the layer structure was designed for the implementation of a pHEMT and not a Gunn diode.

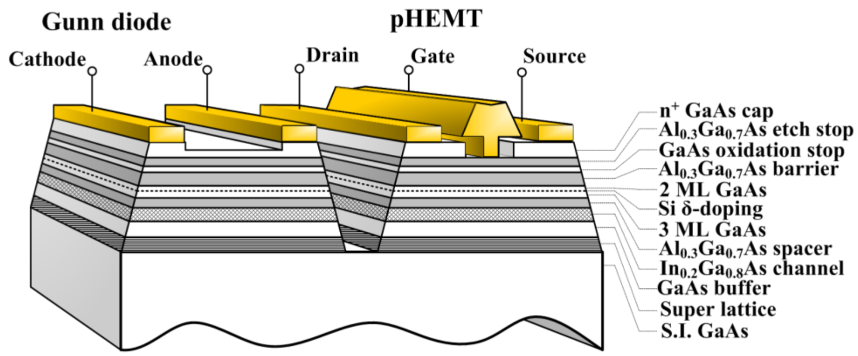
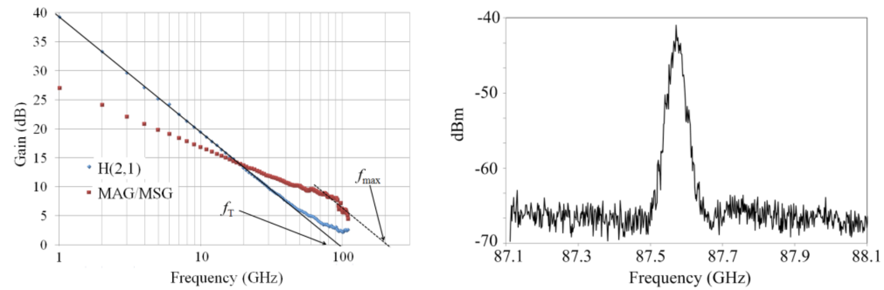


Figure 1. The layer structure and the implementation of the two devices on the same substrate.



(a) (b)

Figure 2. The current gain and the maximum available gain/maximum stable gain versus frequency for a two-finger pHEMT with 12 μm width (a) and the measured spectrum of the 60 μm wide Gunn diode with 1.3 μm anode to cathode seperation (b).

References

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