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New Fabrication Technology Integrating FETs and Diodes

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We demonstrated a new integration technology for FETs and diodes. This technology uses selective area MOCVD (SMOCVD) for FET and diode layer. FETs(called FECFET)fabricated by this technology have very short distance between drain and source, so that the performances such as knee voltage and transconductance are superior to those of conventional MESFET with the same gate length. Because this structure has n^+ contact layer beneath n active layer, it is easy to integrate with high-quality diode having low series resistance. Using this approach, 36GHz single balanced diode mixer and IF amplifier have been fabricated on a GaAs wafer.

1. INTRODUCTION

Since the invention of GaAs FET, MMICs such as amplifiers,switches,mixers and oscillators have been successfully developed. But the complexities of the GaAs MMICs are rather limited due to fabrication difficulties. The main proplem comes from the difficulties of integrating FETs and diodes. Particularly this problem is more severe for millimeter-wave applications. Diodes such as varactors and p-i-n's require thick n^+ contact layer (0.4 - 1μm) beneath the active layer to reduce the series resistances. On the other hand, conventional FETs have n^+ contact layer over the thin active layer. Therefore, when attempting to integrate these devices monolithically, it is necessary to have a compromise between the performances of these devices[1)]. There have been several research approches for the solution of this problem. One of these approaches is selective deep implantation technology[2)]. Selective deep implantion technology is effective to reduce the diode series resistances, but the implantation depth is limited especially for GaAs substrate, and it is difficult to activate the doping concentartion higher than 1x 10^{18}cm/3. In this work, we use SMOCVD to integrate both FETs and diodes on a GaAs wafer. Recently, the SMOCVD technique has been widely used in the fabrication of novel device structures. These include the GaAs floated electron channel field effect transistor (FECFET)[3)] and the GaAs/AlGaAs HBT with reduced base-collector capacitance[4)]. In this paper, The integration of high quality diode and FECFET is reported. 36GHz single balanced diode mixer and IF(intermediate frequency) amplifier are fabricated on a GaAs wafer.

2. INTEGRATION TECHNOLOGY

The layer for FET and diode was grown by atmospheric pressure(AP)-MOCVD system which has a horizontal quartz reactor with a resistive-heated susceptor. Trimethylgallium(TMGa), AsH_3 and SiH_4 are employed as the source and dopant materials. The used substrate is undoped S.I. (100) GaAs wafer. When a SMOCVD is performed over the patterned (100) GaAs substrate which has SiO_2 stripe with orientation 10^o-40^o off the $[\bar{1}10]$direction, an inclined plane is grown and forms an angle of 130^o with respect to the (100) surfaces on the $(\bar{1}10)$cleavage plane. In this experiment, the orientations of SiO_2 stripes are 20^o and 30^o off from the $[\bar{1}10]$ direction. The n^+ contact layer (0.5-0.6μm) and n active layer (0.3-0.4μm) with the doping concentration of $2x10^{17}$cm/3 are sequentially grown on the SiO_2 patterned substrate. During the growth of the active layer, a triangular void is formed. The void height, H, can be empirically expressed as follows [3)]

$H = \beta \cdot D\tan\phi$

where D is the SiO_2 width, β is the lateral growth parameter of about 0.32 and ϕ is the void angle from the substrate of about 60^o (see fig.1). Except for the SMOCVD, the other process is the same as the conventional MMIC process. Fig.1 shows a schematic cross section of the proposed structure. The non-conventional FET part is FECFET(Floated Electron Channel FET)[3)]. Because the effective channel length (the distance between drain and source) is very short, the knee voltage and transconductance of FECFET are superior to those of conventional MESFET with the same gate length. Because this structure has the n^+ contact layer beneath the active layer, it is easy to integrate with high quality diode.

3. RESULTS

The typical ouput characteristic of a FECFET is shown in fig.2. The gate length (L) and the gate width (W) of the FECFET are 1.0μm and 100μm, respectively. As shown in the I-V characteristic, knee voltage is smaller than 0.5 Volts. The typical extrinsic transconductance at zero gate bias is about 200mS/mm.

Fig.3 shows the typical characteristic of an integrated diode with the junction area of $1x30\mu m^2$. The diodes typically exhibit a zero-bias junction capacitance less than 60fF and low series resistance ($5\Omega < Rs < 10\Omega$). Using this diode parameters, the 36GHz single balanced mixer with 2 diodes has been fabricated (see fig.4). Fig.5 presents the conversion loss of the mixer. 35GHz local oscillator (LO) is used. The performance shows the conversion loss less than 8dB at LO power more than 12dB. Fig.6 shows the measured |s21| of 1 stage FECFET feedback amplifier. The gate length and the gate width of the FECFET used for the amplifier are 2.0μm and 600μm, respectively.

4. CONCLUSION

In this report, we demonstrated a new integration technology for FETs and diodes. This technology uses SMOCVD for FET(FECFET) and diode layer. 1.0μm(L) ×200μm(W) FECFET demonstrates a small knee voltage (<0.5Volts) and a high transconductance(typically about 200mS/mm at zero gate voltages). Because this structure has n^+ contact layer beneath the active layer, it is very useful for the integration with high-quality diodes having low series resistances. Fabricated diodes with the junction area of $1x30\mu m^2$ typically exhibit a zero-junction capacitance less than 60fF and low series resistances ($5\Omega < Rs < 10\Omega$). Using this approach, 36GHz single balanced diode mixer with the conversion loss less than 8dB and single stage feedback FECFET IF amplifier have been fabricated on a single GaAs wafer.

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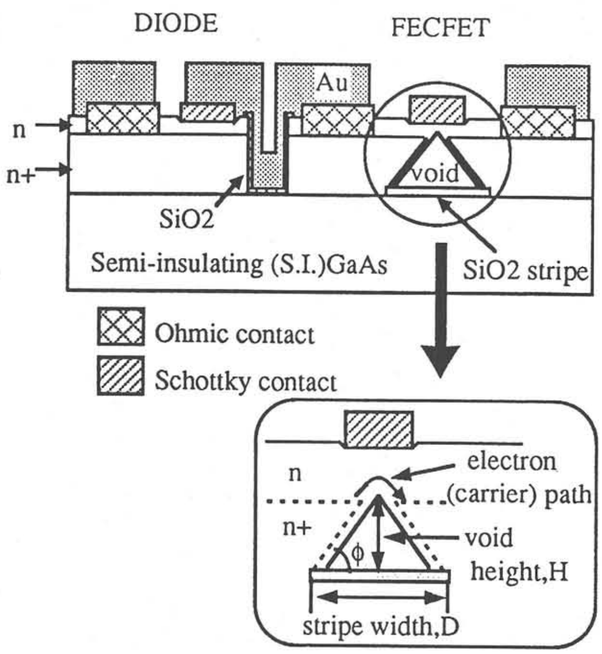

Fig.1. A schematic cross-section of the proposed structure. The interconnection between the diode and the FECFET can use airbridge structure or SiO2 insulating layer as shown.

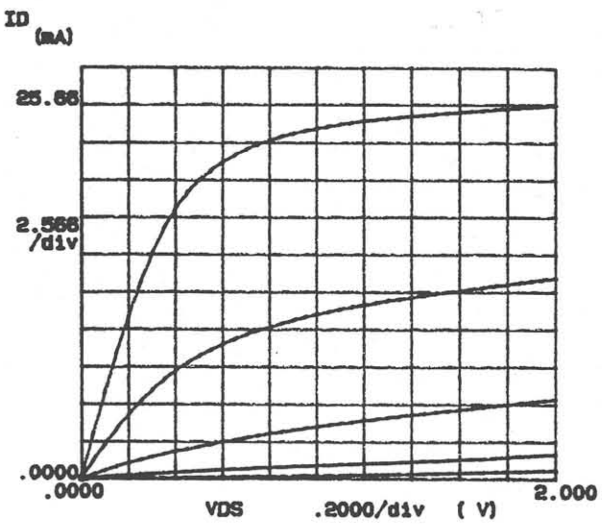

Fig.2. The I-V characteristic of a typical FECFET (L=1μm;w=200μm;Top side: Vg=0V;-0.5V step)

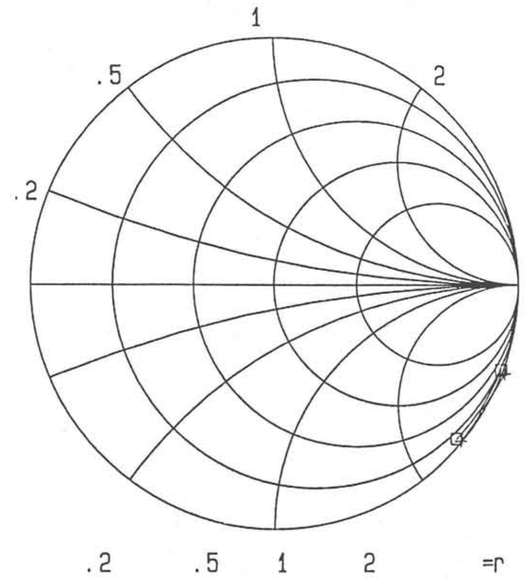

Fig.3. The s11 characteristic of the fabricated diode (The junction area= 1x30μm²) at zero bias. (Freq : 8GHz ~ 16GHz)

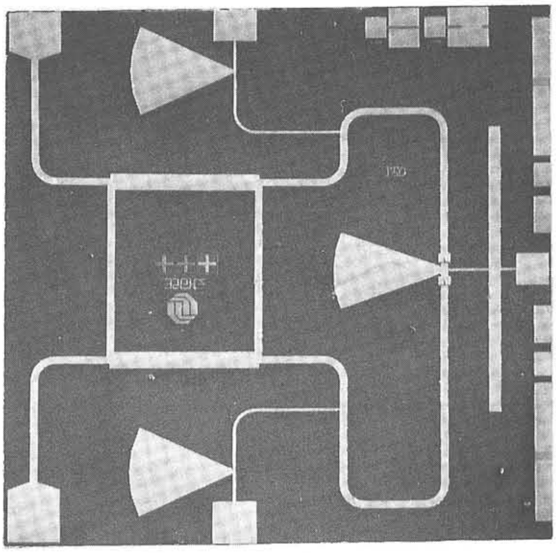

Fig.4. Photograph of the fabricated mixer

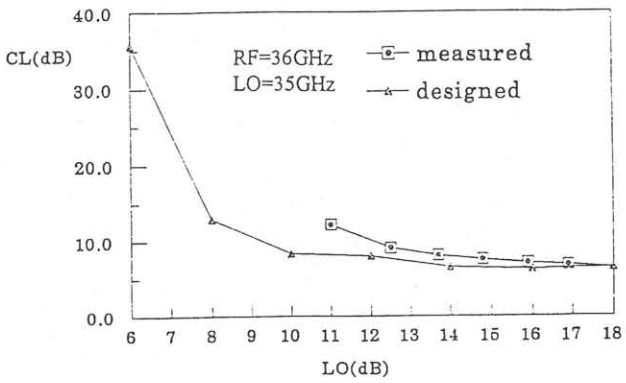

Fig.5. Convertion loss (CL) of the 36Gz diode mixer

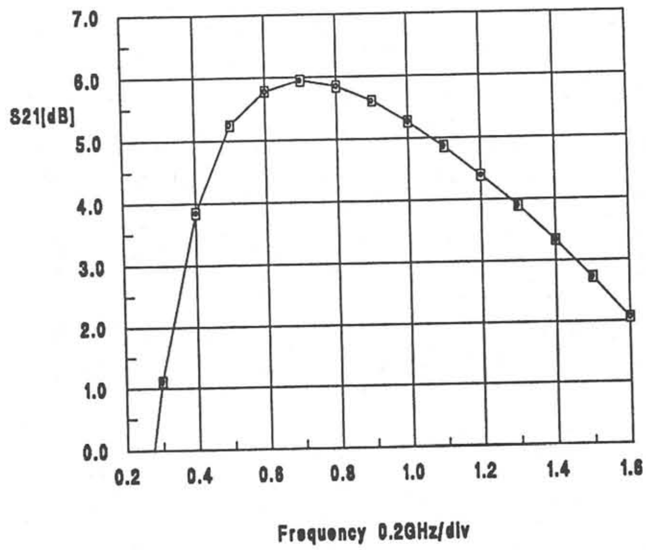

Fig.6. The measured result of the single stage FECFET feedback amplifier .(L=2μm,W=600μm)