ULTRA BROAD BAND MONOLITHICALLY INTEGRATED HBT MIXER

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Abstract

A monolithically integrated HBT mixer has been designed, fabricated and measured. This mixer is based on a Gilbert cell [1] for ultra broad band application. Positive conversion gain up to 18.5 GHz has been measured. To authors' knowledge this is the first monolithically integrated HBT mixer reported with such high operating frequency.

Introduction

One of the key components of an heterodyne receiver transmitter is the mixer. This circuit must provide both broad bandwidth and possibility of up and down conversion. Up to now monolithically integrated HBT [2] MESFET [3] and silicon BJT [4] mixers have been reported. MESFET and silicon BJT technological process required either sub-micronic photolithography or sophisticated sub-micronic self-aligned process whereas in our circuit a very simple technological process has been used. Only 12 mask levels and a 2µm photolithography are required to realise our circuit.

HBT structure and process

Table 1: Material structure of HBT.

Layer N°.	Description	Concentration (cm^{-3})	Thickness (Å)
7	n GaAs	4.0E18	1500
6	n $Al_xGa_{1-x}As$ (x=0.3 to 0)	5.0E17	300
5	n $Al_xGa_{1-x}As$ (x=0.3)	5.0E17	1900
4	n $Al_xGa_{1-x}As$ (x=0 to 0.3)	5.0E17	300
3	p GaAs	4.0E19	1000
2	n GaAs	2.0E16	12000
1	n GaAs	4.0E18	10000

The AlGaAs/GaAs heterostructure was grown by MOCVD on a 2-inch diameter semi-insulating GaAs substrate. The detailed layer structure is presented in Table 1. Carbon and Silicon were used as p and n-type dopants, respectively.

After MOCVD growth, MMICs with double-mesa HBTs were processed. The HBT devices exhibit an emitter stripe width of 2 µm, length in the range of 20 to 240 µm, and 16 emitter stripes for large devices. The capacitors were made with silicon nitride, the resistors with a thin Ti/Pt layer and the inductors with a Ti/Au layer. The main characteristic of the developed technology is its ability to fabricate simultaneously active and passive devices in one hand, high and low power HBT in the other hand.

Circuits fabrication is based on contact photolithography and starts from etching the two mesas. Wet etching was used to contact the base layer (3), while the subcollector layer (1) was contacted, first by ion milling etching and then adjusted by wet etching [5].

B-H isolation implantation determines the active areas. This step requires a thick silicon nitride / photoresist mask [6].

AuGeNi/Ag/Au film is further evaporated and lifted-off, and emitter and collector ohmic contacts are formed by annealing at 430°C. P-type ohmic contacts for the base are formed by evaporation Mn/Au/Ti/Au layers, alloyed at 300°C. The contact resistivity of the base is extremely low such as 8 x 10^{-7} $\Omega.cm^2$ [7].

The two following steps are specific to power devices (Fig. 1) to reduce emitter resistance and permit high current in the emitter fingers. First, a 2000Å layer of silicon nitride is deposited by PECVD and dry etched on each emitter metalisation. This layer contributes to the surface passivation. Then, a Ti/Au film is evaporated and lifted-off. This layer is also used to realise the first interconnection level of the MMICs.

The following steps are required for the MMICs fabrication.

A Ti/Pt film (20 Ω/□ resistance) is evaporated and lifted-off to fabricate the resistors.

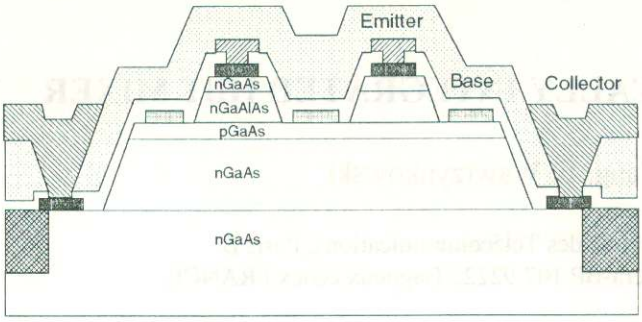

Fig 1 : Cross-section of power HBT.

A silicon nitride layer is deposited as a dielectric film for the capacitors.

Then, the mesa structure is planarised with a 1.2µm polymide layer, etched by O_2 and CHF_3 reactive ion etching (RIE) in two steps. One step allows us to determine the capacitors' areas and the other to achieve interconnection vias.

At last, the second interconnections level is fabricated by evaporating 200Å/12000Å Ti/Au metal film, defined by ion milling etching. This step completes the MMICs fabrication. Transistors have been measured using cascade microwave probes. Very accurate models have been extracted for each type of transistor. Monolithically integrated HBT mixers have been designed and fabricated using this technological process.

Design

The circuit shown in Fig. 2 is based on a Gilbert multiplier cell [4]. The LO power drives the lower differential pair while the RF power drives the cross-coupled quad of transistors leading to the actual frequency mixing. To improve the bandwidth of the Gilbert cell a transimpedance amplifier has been used. The principle of this broad band amplifier is to reduce the Miller effect [8]. The signal is then shifted by two pairs of emitters followers to the input of an asymmetric open collector output buffer. Non-linear simulations have been carried out using an accurate HBT model. Good agreement between simulated and measured results have been found. A microphotograph of the mixer chip is shown in Fig. 3.

Results

The circuit has been tested with an input LO power of -3 dBm and an input RF or IF power of -20 dBm. For down conversion ($F_{RF}=F_{LO}$-70 MHz), positive RF power conversion gain up to 12.5 GHz has been obtained with IF of 70 MHz. For up conversion ($F_{RF}=F_{LO}$+70 MHz), positive conversion gain has been obtained up to 6.5 GHz (Fig. 4). With an input LO power of 13 dBm, positive conversion gain has been obtained up to 18.5 GHz for down conversion, and up to 10.5 GHz for up conversion (Fig. 5). The circuit power consumption is 430 mW. These results are comparable with a reported monolithically integrated mixer, using sophisticated submicronic self-aligned silicon bipolar transistors [4].

Conclusion

A monolithically integrated HBT mixer has been designed, fabricated and measured. This circuit has been realised with a very simple non-self aligned technological process. The mixer provides positive conversion gain up to 18.5 GHz for down conversion and up to 10.5 GHz for up conversion.

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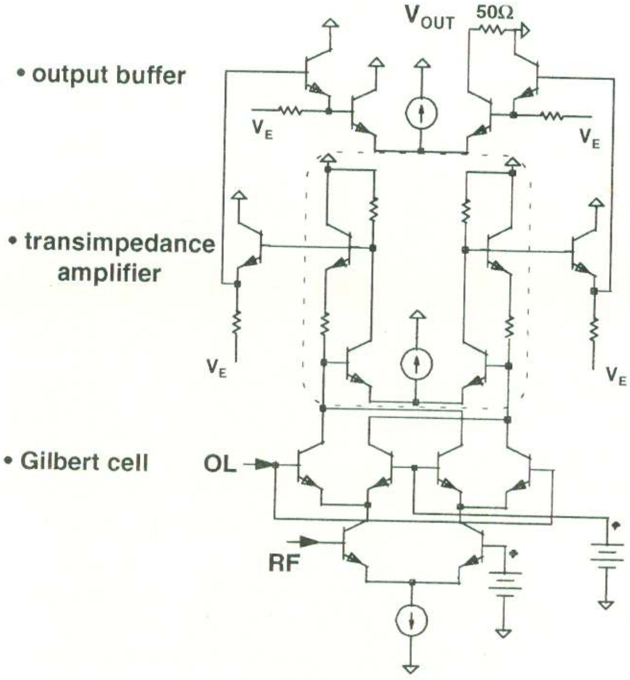

Fig. 2 : Mixer circuit schematic.

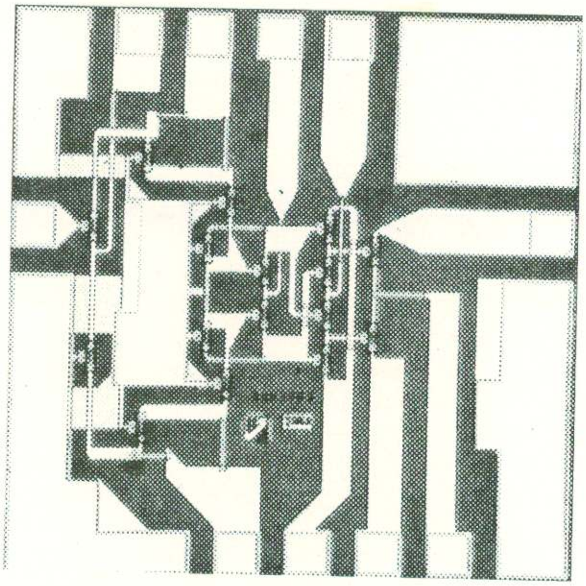

Fig. 3 : Microphotograph of MMIC mixer (1.2 mm x 1.2 mm).

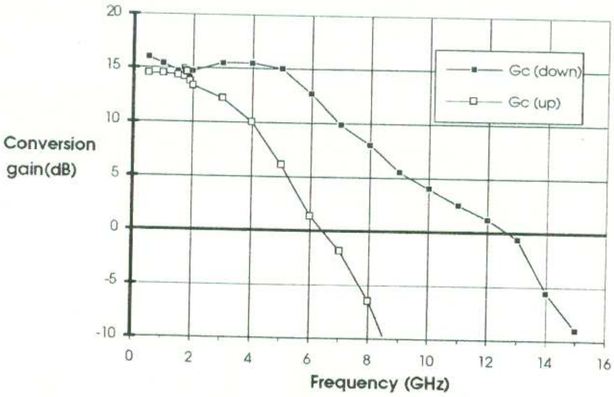

Fig. 4 : Conversion gain versus LO frequency, P_{LO}=3dBm, P_{RF}=-20 dBm, F_{FI}=70 MHz.

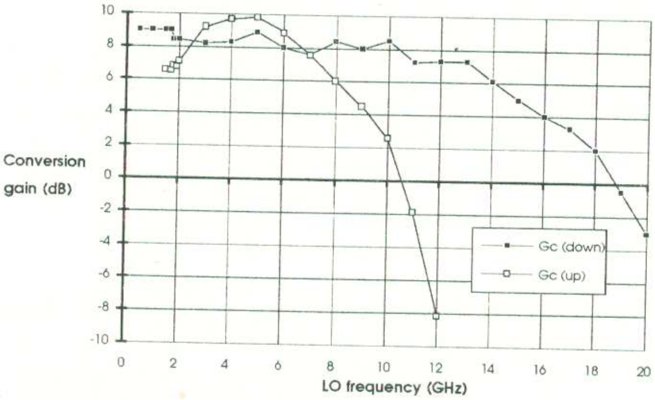

Fig. 5 : Conversion gain versus LO frequency, P_{LO}=13dBm, P_{RF}=-20dBm, F_{FI}=70 MHz.