GaAs MMIC Activities in NEDI

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Abstract: This paper reviews the principal activities of NEDI in the field of GaAs MMIC's with the emphasis on the fabrication technologies and products characteristics. It also describes some highlights of NEDI MMIC development and key resources of NEDI MMIC work.

Key Words: GaAs MMIC, MESFET, PHEMT, HBT, Fabrication technologies

I. INTRODUCTION

Nanjing Electronic Devices Institute (NEDI), founded in 1958, is mainly engaged in microelectronics, optoelectronics and vaccum electronics. GaAs MMIC is the one of its most important fields on research, development and production with following highlights.

- Starting in 1978
- First GaAs MMIC (X band oscillator MMIC) in China in 1980
- First paper on chinese GaAs MMIC reported on IEEE MTT-s International Microwave Symposium in 1981
- Own-designed and made Φ2" GaAs high pressure LEC crystal puller in 1983
- First chinese Φ2" GaAs processing line in 1990
- First chinese Φ3" GaAs processing line with MMIC CAD center and heterojunction epitaxial materials laboratory in 1996
- Own-designed and made Φ3"/4" GaAs high pressure LEC crystal puller in 1997
- Over 150 prototypes and products of GaAs MMIC

II. GaAs MMIC RESOURCES

NEDI is possessed of many valuable resources for GaAs MMIC regarding the building, the equipment and instrument, the manpower as well as the technology.

- Engineers: 65 (including professors and senior engineers)
- Clean room: 1500m^2 (including 60m^2 class 10 photolithography area)
- Materials:

  Δ High pressure LEC crystal pullers for Φ2", 3"/4" GaAs ingot Δ MBE for Φ3" GaAs wafer Δ MOCVD for Φ2", 3" 4" GaAs wafer
- Design:

  Δ Workstations: HP9000/700, SUN 10 Δ Microwave devices ,circuits design and analytical softwares: Ansoft, HP-EESOF, Compact Explore, GATES POSES, MDS, ADS, IC-CAP, Cadence

- Mask: Δ Pattern generator Δ Repeater
- Chip fabrication

Δ Steppers, G-line, I-line Δ DUV mask aligner Δ IR backside aligner
Δ track Δ PECVDs Δ RIEs Δ Spray etcher Δ Ion implanters
Δ RTA Δ EB evaperators Δ Sputtering systems Δ Wafer lapping machines Δ Wafer polishing machines Δ Dicing system
Δ Wire bonding machines Δ Die bonding machines

- Diagnostics

Δ Scanning electron microscope Δ 1500 x optical microscopes
Δ Ellipsometer Δ Hall effect measurement system
Δ C-V profiler Δ Alpha step film thickness meter
Δ Stress measuring system

- Test

Δ Network analyzers Δ Spectrum analyzers
Δ Noise analyzers Δ Power testers
Δ On-wafer autoprobers Δ Parametric tester

III. GaAs MMIC FABRICATION TECHNOLOGIES

NEDI has successfully established 3 kinds of Φ3” GaAs fabrication technologies with some features

1. Ion implantation MESFET process

- Forming a n active layer for the channel and a n^+ Ω contact layers for the source and drain by ion implantation
- Rapid thermal annealing with a special dielectric encapsulation for increasing the activation and improving the uniformity.
- I-line stepper lithography to print 0.5 μ m gate
- Si_3N_4 passivation for power devices to obtain the breakdown voltage of larger than 15V
- Air bridge and backside via hole
- Si_3N_4 and Ta_2O_5 MIM capacitors
- Yield ≥90%
- Power: 0.5W/mm(10W C band)

2. MBE PHEMT, HFET PROCESS

- Unique optical lithography method to realize 0.25 μ m T-shape gate structure
- Double recess to obtain higher breakdown voltage

- Power: 1 W/mm (X band) and 300mW (34GHz)

3. MOCVD HBT process

- H^+ implantation for limiting the E—B junction area and realizing the device isolation as well as minimizing the device parasitic effect
- Breakdown voltage of the power device can reach to 20V
- Stepper lithography to print the E and B with the 0.5 μ m space between them
- Air bridge with SiN passivation and backside via hale
- SiN MIM capacitor
- Power: 3W/mm (X band)

4. Process control monitor (PCM) and statistical process control (SPC)
PCM and SPC are employed on the processing line to monitor the process parameters and improve the yield.

5. Processing capacity
250 wafets/week

IV. GaAs MMIC PROTOTYPES AND PRODUCTS

A partial list of GaAs MMICs that NEDI has developed is given below

- Power application: power amplifier driver amplifier
- Receiver use: low noise amplifier mixer
  oscillator/vco buffer amplifier
- Controlled circuits: switch (SPDT, DPDT) phase shifter (analog, digital)
  attenuator (analog, digital) limiter
- Others: active filter active circulator
- Frequency range: L to Ku band

Some typical GaAs MMIC prototypes and products with main characteristics are depicted as follows.

- S-band MMIC frequency-variable front-end receiver
  RF frequency: 2.0-2.5GHz IF frequency: 30-200MHz
  N_F < 1.5dB G_P 50 ±0.5dB
  LO power <5dBm VSWR <1.5

- C-band MMIC internally-matched power amplifier
  Frequency: 5.2-6.2GHz G_P>11dB P_{out} 3w

- X-Ku band MMIC power amplifier
  Frequency 9-13GHz G_P 13dB P_{out} 2w

- 2-6GHz MMIC power amplifier
  G_P 17dB Flatness ±1dB P_{-1} 29-30dBm

- 2-20GHz MMIC distributed power amplifier
  G_P 7.5 ±1dB P_{out} 23dBm

- MMIC family for T/R module use Frequency 9.3010.4GHz
  MMIC power amplifier: P_o1-1.5w, G_P15-20dB
  MMIC5 bit phase shifter: IL 9.5dB, VSWR 1.5 Phase error (RMS) 3°
  MMIC SPDT switch: IL 1.5dB ISO 25dB

- MMIC DPDT switch Frequency 870-970MHz IL 0.8dB
  ISO 20dB VSWR < 1.2
  $P_{-0.1}$ 33dBm Control voltage 0,-3V