M. Bartocci, C. Lanzieri*, M. Peroni*

ELETTRONICA S.p.A., Unità Tecnica Progettazione Microonde, 00131 Roma, Italy
*ALENIA un'Azienda Finmeccanica, Direzione Ricerche, GaAs Integrated Circuits, 00131 Roma, Italy

Title: A 0.5-30 GHz monolithic pHEMT amplifier for ESM systems applications

Introduction

ESM wide open receivers have need, next to antenna, to a wide bandwidth preamplifier with a low noise figure, in order to increase the sensitivity.
It is also important to have a high output third order interception point to reduce the harmonics and spurious.
For this reason a low noise MMIC GaAsFET Pseudomorphic HEMT amplifier has been designed and developed in collaboration with Alenia Ricerche Foundry.
Based on a travelling-wave amplifier structure, this component has good performances in term of noise figure, bandwidth, return loss and output power.

Circuit design

GaAsFET's have high input and output admittance, that reduce in a distributed amplifiers the cut-off frequencies and consequently the bandwidth.
Using a travelling-wave configuration we have calculated the high impedances gate line and drain line in order to obtain a high frequency cut-off.
Being in a GaAsFET $C_{GS} > C_{DS}$, the amplifier frequency cut-off is FCG:

$$F_{CG} = 1 / (\pi * Z_{OG} * C_{GS}) \qquad F_{CD} = 1 / (\pi * Z_{OD} * C_{DS})$$

Alenia GaAsFET's that we have used for this amplifier have a low gate length (0.25μm), that permit to obtain a F_{CG} up to 30GHz.
Using S parameters measured with wafer on test at different d.c. bias voltages and TRL deembedding method, we have simulated and optimised by MDS (HP) software two amplifiers.
Both circuits use three stages of gain, the first circuit was designed to obtain a nominal gain of ≈ 5 dB, across the frequency range 0.5-30GHz, the second circuit was designed to obtain a nominal gain of ≈ 7 dB across the frequency range 0.5-22GHz.
The design has been done tending into account the stability, return loss and flatness.
Using the Alenia Pseudomorphic HEMT technology (0.25μm x 100μm) we have obtained a low noise figure.
The simulation results are illustrated in fig.1.
The circuit layout dimension has been optimised reducing the number of components, the areas of capacitors and the structure of the drain and gate lines.
An input DC block capacitor was introduced for obtain a 0.5GHz lower bandwidth limit.
In fig. 2 are illustrated the amplifiers layouts circuits.

Technology

The epitaxial layers composing the PM-HEMT structure have been grown on 2-inch diameter, semi-insulating LEC GaAs substrates by molecular beam epitaxy.
The fabrication process for the PM-HEMT devices is based on: Source-Drain ohmic contacts formed by rapid thermal alloying of a Au Ge Ni metallisation scheme, planar isolation by proton implantation, conventional optical lithography for sub-micron Gate length, highly selective GaAs/Al GaAs etch solution for channel recessing, Ti/Al Gate metallisation, plasma

enhanced chemical vapour deposition for device passivation and finally Ti/Pt/Au overlayer metallisation. After Gate metallisation and lift-off, effective device Gate length is controlled by means of highly selective, low damage plasma etching of the Ti barrier metallisation. With this technique it is possible to reduce the effective Gate length from the as-deposited dimension of ≈ 0.8 μm down to less than 0.3 μm without any noticeable deterioration in fabrication yield. The resultant "T-shaped" Ti/Al Gate structure, similar to what is obtained by e.b. lithography, is found to have very good on-wafer uniformity and excellent processing reproducibility (fig.7)

Experimental results

The results of the LNA circuit 0.5-22GHz measured on-wafer are illustrated in fig.3.
A circuit was mounted in an millimeter test jig for measurement across the temperature range -55°C to +85°C.
The measurement are illustrated in fig.4.
The gain, with the test jig contribution is ≈ 5.0 dB. The return loss is better than 10dB and the noise figure is less than 5dB over the 6-21GHz bandwidth at room temperature.
The temperature gain and noise figure dependence is 0.012dB/°C.
The output power at 1dB gain compression is greater than 8dBm across the band 0.5-22GHz. In fig.5 are illustrated the measurements find out to a double MMIC.
The gain at room temperature across the band 0.5-22GHz has a positive slope from 10dB to 13dB. The input and output return loss is better than 10dB.
The output 1dB gain compression is better than 8dBm and the noise figure is better than 6dB across the band 6-22GHz.
The gain and noise figure dependence is ≈ 0.02dB/°C.
As we can see from the fig.6, the gain control from Vgate polarisation has the potential for reduce the temperature dependence or to introduce a variable isolation.

Conclusion

A 0.5-22GHz and a 0.5-30GHz travelling amplifier utilising three 0.25-100μm linear FETs were designed and realised in cooperation with Alenia Ricerche Roma Tiburtina Foundry.
The benefits of pHEMT technology offers highest gain, bandwidth and lowest noise figure compared to that of the GaAS MESFET technology.

Acknowledgements

The authors wish to thank Mr. F. Magrini and Mr. M. Di Rocco for their assistance during the realising of the amplifiers.

References

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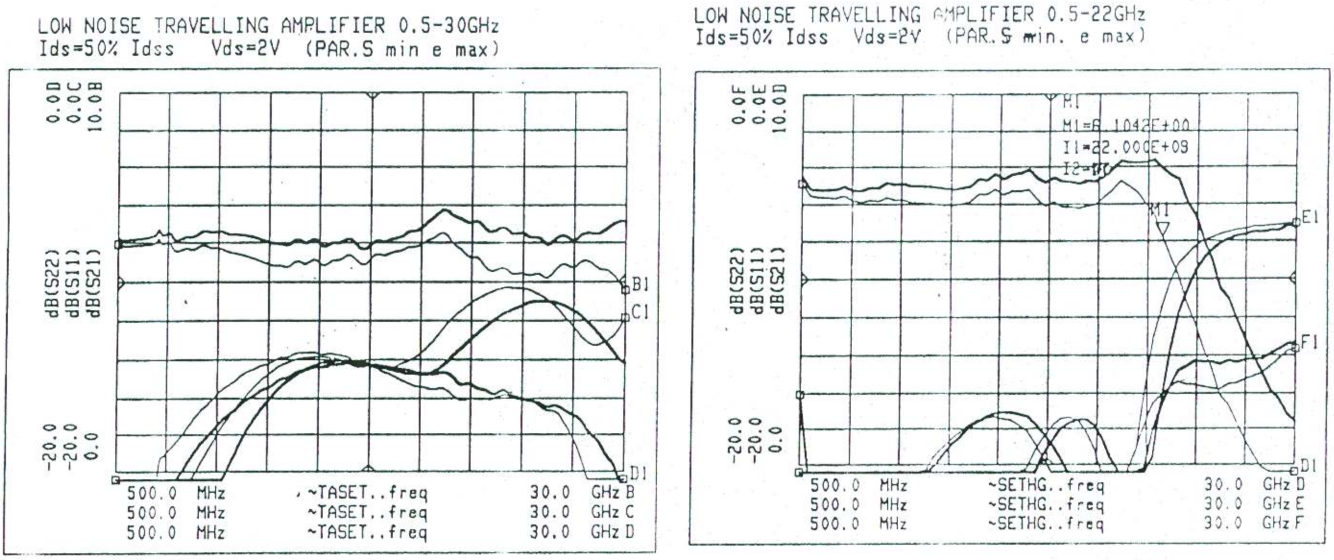
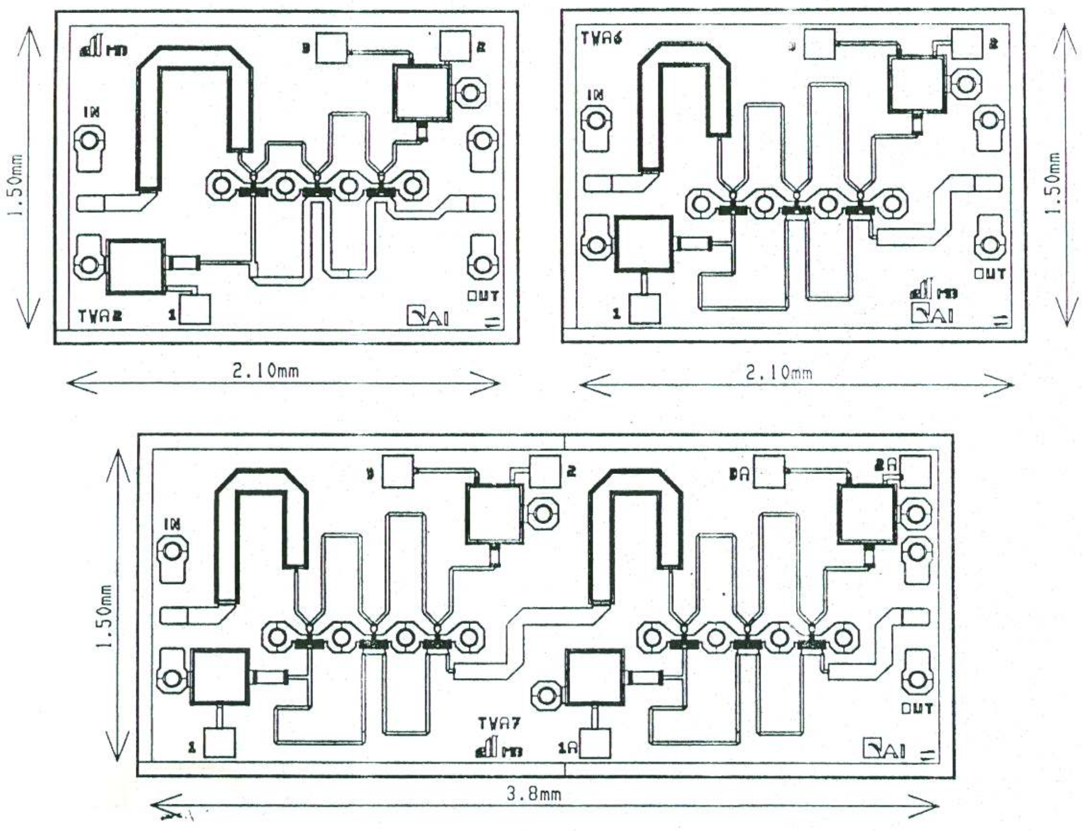


LOW NOISE TRAVELLING AMPLIFIER 0.5-30GHz
Ids=50% Idss Vds=2V (PAR.S min e max)
dB(S22) dB(S11) dB(S21)
500.0 MHz ~TASET..freq 30.0 GHz B
500.0 MHz ~TASET..freq 30.0 GHz C
500.0 MHz ~TASET..freq 30.0 GHz D
LOW NOISE TRAVELLING AMPLIFIER 0.5-22GHz
Ids=50% Idss Vds=2V (PAR.S min. e max)
500.0 MHz ~SETHG..freq 30.0 GHz D
500.0 MHz ~SETHG..freq 30.0 GHz E
500.0 MHz ~SETHG..freq 30.0 GHz F

Fig. 1



1.50mm
2.10mm
TVA6
TVA7
3.8mm
IN
OUT

Fig. 2

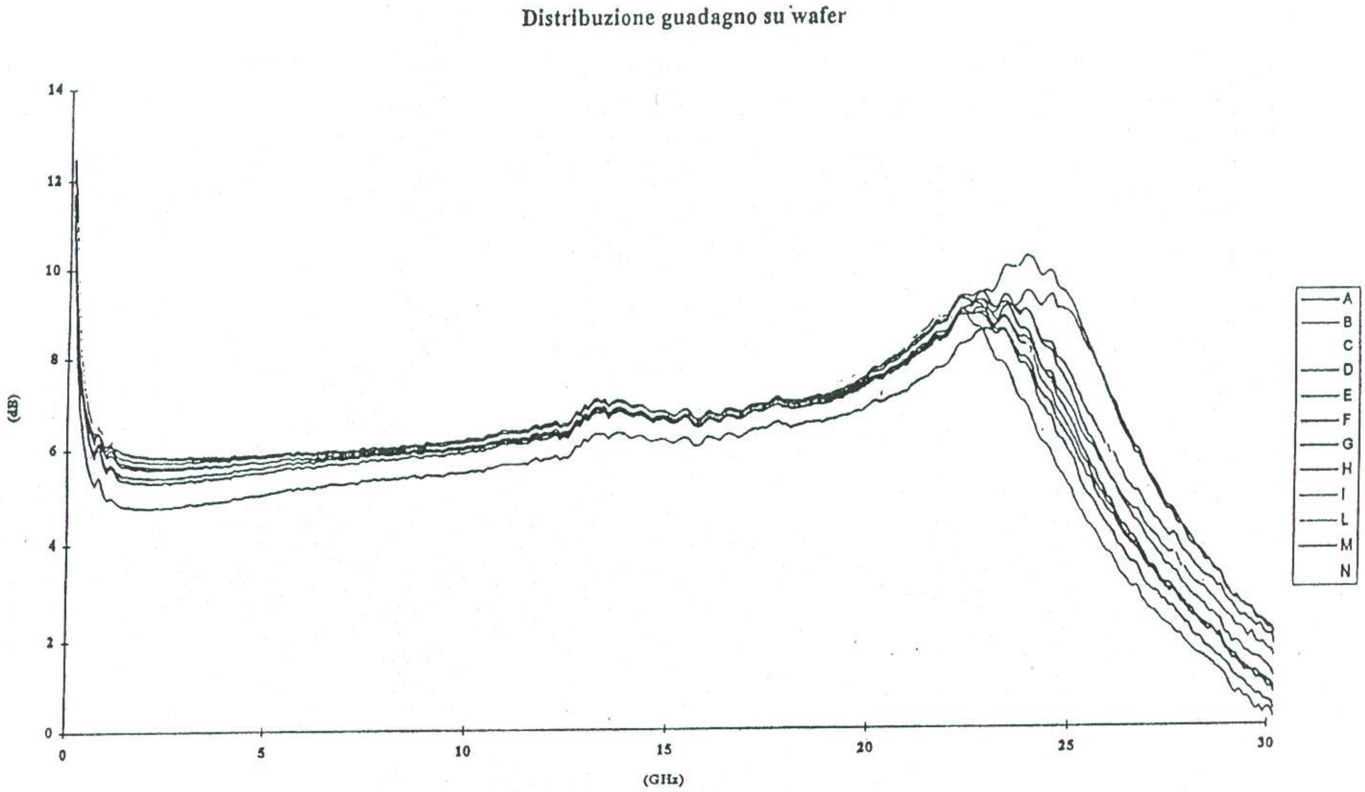

Distribuzione guadagno su wafer
(dB)
(GHz)
A
B
C
D
E
F
G
H
I
L
M
N

Fig. 3

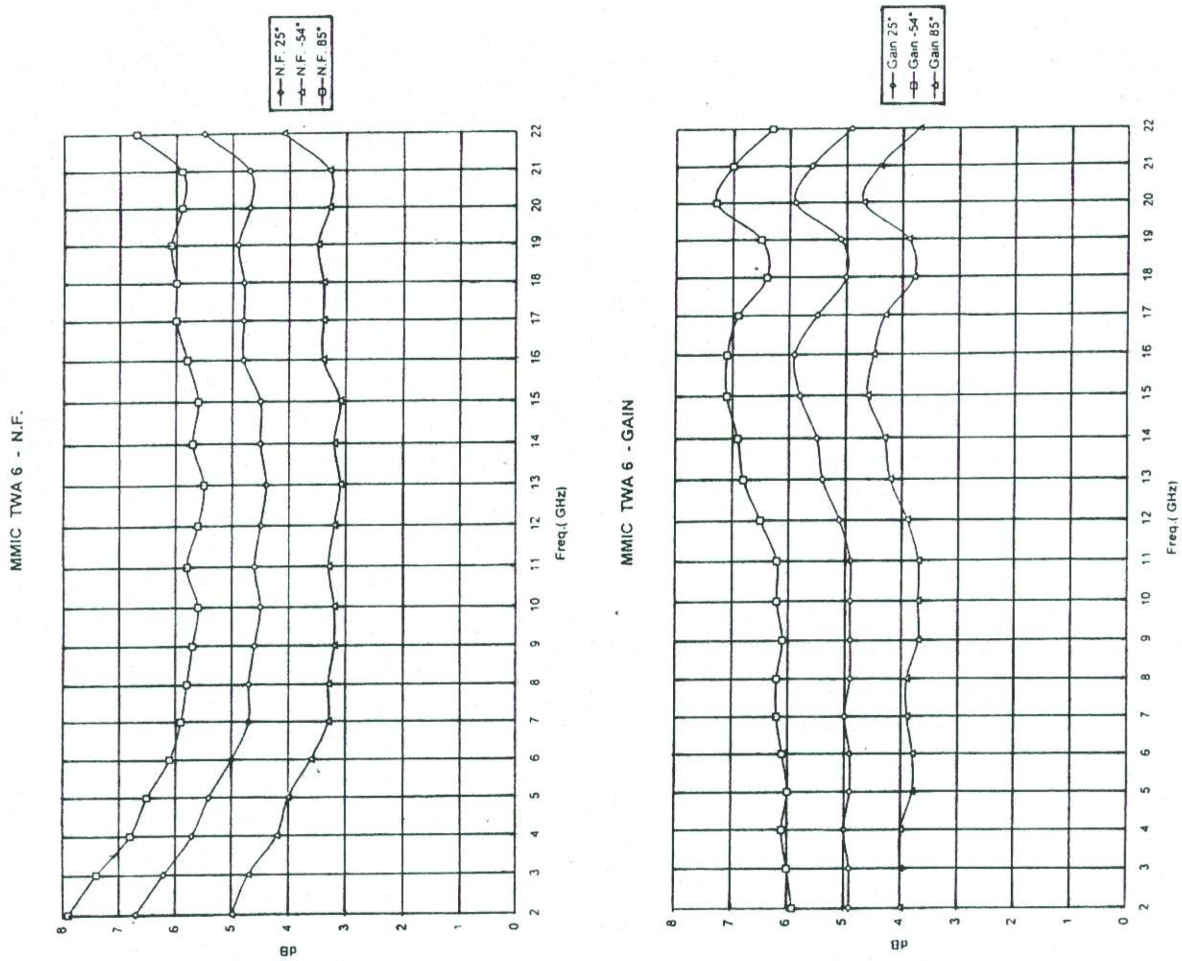

MMIC TWA 6 - N.F.
N.F. 25°
N.F. -54°
N.F. 85°
Freq.(GHz)
dB
MMIC TWA 6 - GAIN
Gain 25°
Gain -54°
Gain 85°
Freq.(GHz)
dB

Fig. 4

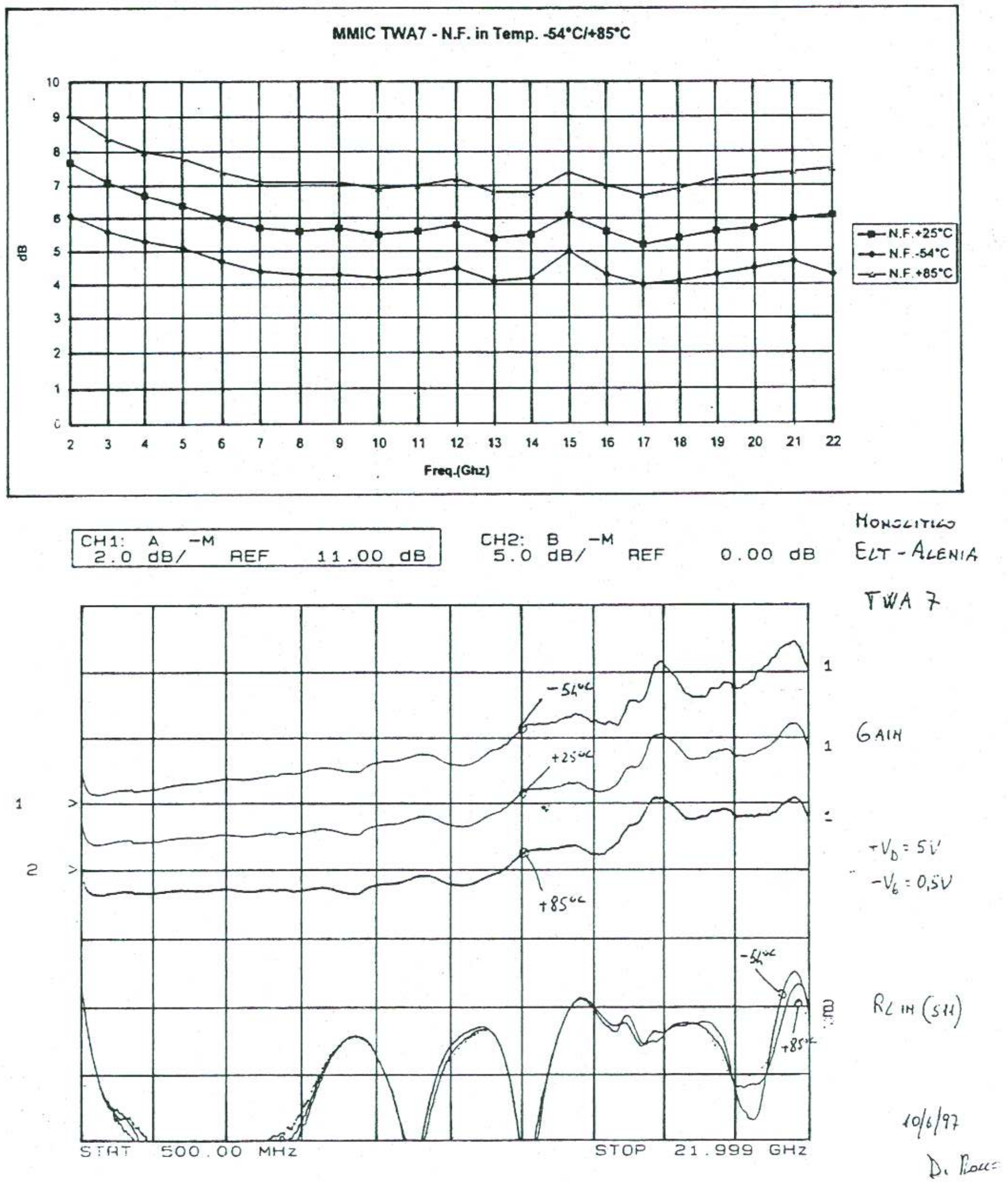


Fig. 5

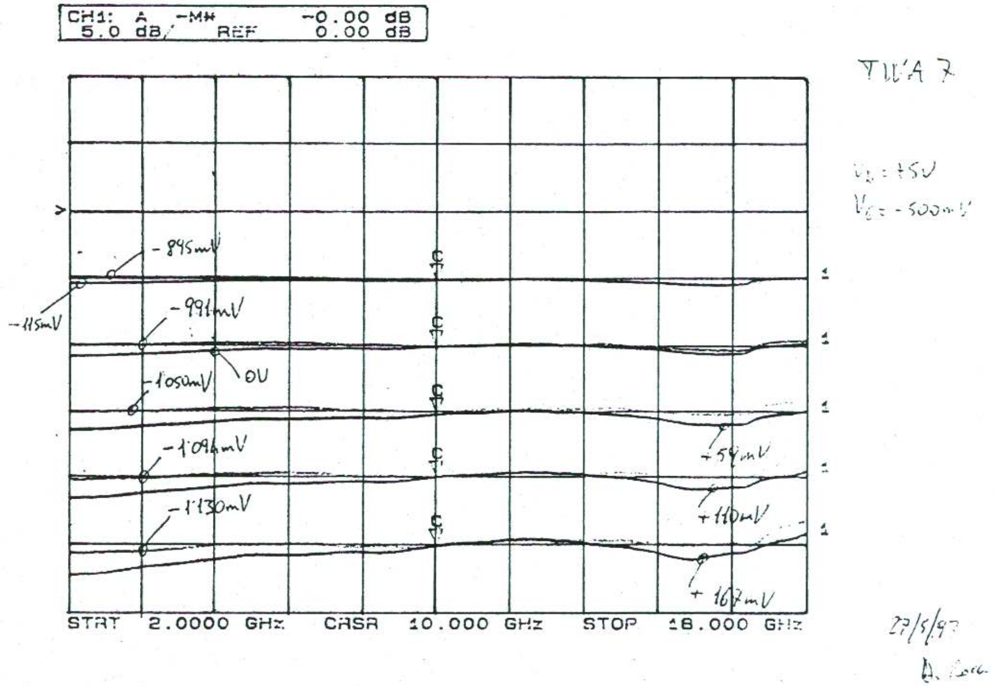


Fig. 6

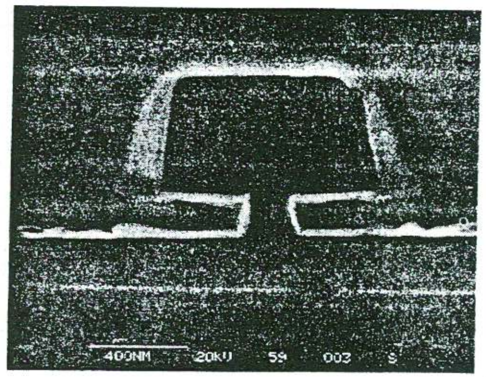


Fig. 7