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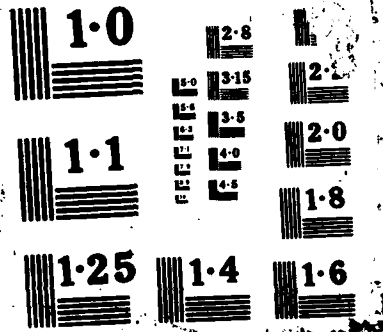
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"Focused Ion Beam Fabrication of Graded Channel Fet's in GaAs and Si"

SEMI-ANNUAL TECHNICAL REPORT

1 July, 1987 to 31 December, 1987

by John Melngailis

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Focused Ion Beam Fabrication of Graded Channel Field Effect Transistors in GaAs and Si

Introduction and Summary

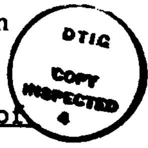
The goal of our research is to exploit the novel capability of the focused ion beam to implant dopants whose density is a function of the lateral position. Thus, FET's in GaAs and Si can be fabricated with a gradient of doping from source to drain. We have fabricated and tested such graded FET's in GaAs and have fabricated Si devices up to the point of focused ion beam implantation. In addition, programs for modeling the devices on the computer have been written. Recently, we have conceived and fabricated a new device: a tunable Gunn oscillator which makes use of doping gradients. To carry out these implantations we have further developed the performance of our focused ion beam machine.

Personnel Working on the Program

Jarvis B. Jacob, Graduate Student, Electrical Eng. and Computer Science
Henri Lezec, Graduate Student, Electrical Eng. and Computer Science
Christian Musil, Graduate Student, Physics
Khalid Ismail, Graduate Student, Electrical Eng. and Computer Science
Len Mahoney, Lincoln Laboratory
Dimitri Antoniadis, Assoc. Prof. of E.E. & C.S., Co-Principal Investigator
John Melngailis, Principal Research Scientist, R.L.E., Principal Investigator

Progress During the Fifth Half Year Period

During this period, our work has concentrated on further machine development, machine testing by exposure of PMMA, and on the fabrication and testing of tunable Gunn diodes.



1 - Machine and Technology Development and Verification by Exposure of PMMA

The purchase of our focused ion beam implanter as well as the development of the machinery has been funded by the Microsystems Technology Laboratories at M.I.T.. However, some fabrication capabilities needed to be developed as part of this contract to carry out the graded implants aligned to features fabricated by standard lithography steps.

Procedures for calibrating the beam deflection against the laser interferometer controlled stage displacement were developed. This was needed to carry out alignment to existing features and abutment of fields so that features larger than the 128 x 128 μm deflection field can be written. An example of a field abutment test pattern is shown in Fig. 1. The offset of lines crossing from one field to another is seen

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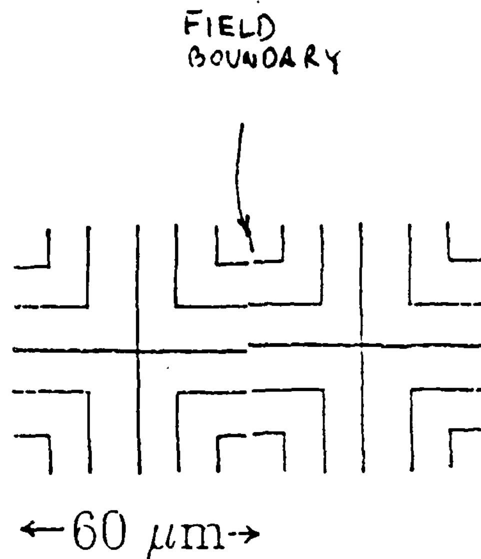


Fig. 1 Results of field abutment testing performed by exposing the pattern shown in the upper left in a repeated fashion. The stage is moved after each exposure. Its position is read by the laser interferometer to ±0.01 mm, and the deflection field is displaced to correct for the difference between the achieved and the desired stage location. The abutment error shows up as a discontinuity or shift in the lines as they cross the field boundary. The maximum abutment error is seen on the right to be 0.07 mm.

Fig. 2 A grating (top) and a square ring produced by focused ion beam lithography in 0.3 μm thick PMMA (as in Fig. 6a) followed by e-beam evaporation of 0.1 μm gold and liftoff.

to be less than 0.1 µm. Our ability to align focused ion beam implants to existing features is of similar high accuracy.

In addition, we have demonstrated PMMA exposure with 0.1 µm linewidth and produced patterns using evaporated metal lift off with the same 0.1 µm linewidth, as shown in Fig. 2.

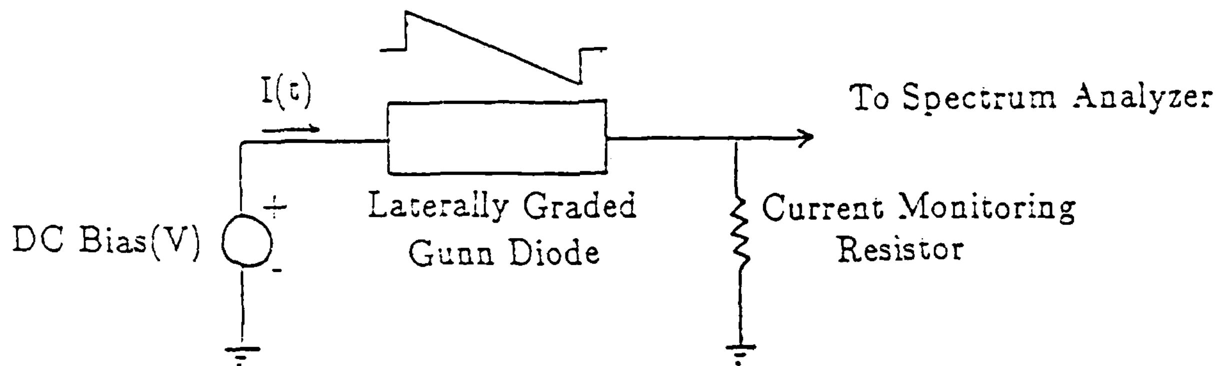
To make pattern generation for the focused ion beam machine more convenient, we have developed a system for transferring patterns from the computer aided design facility where they are drawn in workstations using the program KIC,a standard integrated circuit design software, to the focused ion beam control computer directly. This will make easier any device fabrication where steps are carried out sequentially by conventional fabrication and by focused ion beam fabrication.

The focused ion beam column was characterized extensively and the minimum beam diameter was found to be 0.1 µm. At Hughes Research, identical columns have achieved 0.05 µm. We also found that considerable electrostatic beam steering and offset signals were needed to thread the beam through the column. This indicates a mechanical misalignment. We therefore dismantled the column and flew with the upper part to Hughes where we realigned it using their guidance and expertise. (We now feel we have the expertise to realign the column ourselves also, if needed.) The column is now being reassembled.

2 - Tunable Gunn Diodes

We have conceived of a novel device application of focused ion beams, a tunable Gunn diode, and have built a device demonstrating the concept. In this device, a gradient of doping is implanted between the two contacts. Thus, the distance that a Gunn domain can propagate depends on the D.C. bias. This mean that the frequency can be tuned by tuning the bias. The results are shown in Figures 3 and 4. This device is tunable from 6 to 23 GHz. The power output is -40dBm. Other Gunn oscillators built with other doping profiles had outputs of -10dBm. For example, if a step in doping is produced as a function of distance between the contacts, then the frequency can be shifted between two values as the bias is changed. (A manuscript describing the work done so far is being prepared for publication.)

Current Spectrum Measurement



Frequency Smoothly Tunable w/ DC Bias

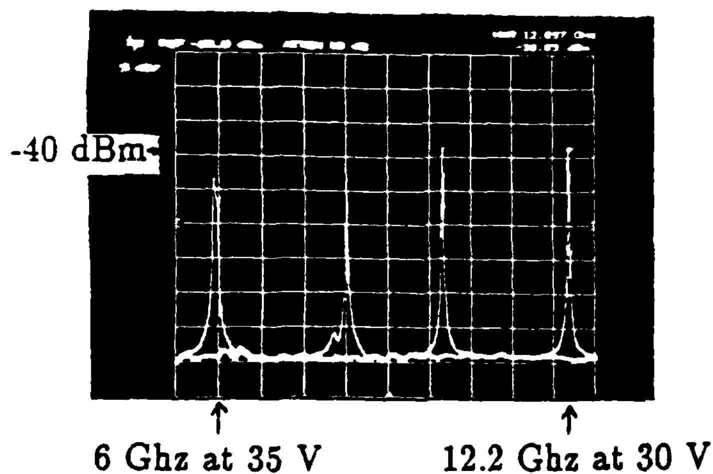


Fig. 3 Tunable Gunn diode. The measuring circuit and schematic of the device which has a gradient between the contacts are shown at the top. Spectrum analyzer output is shown at the bottom. The output frequency shifts smoothly as a function of bias voltage.

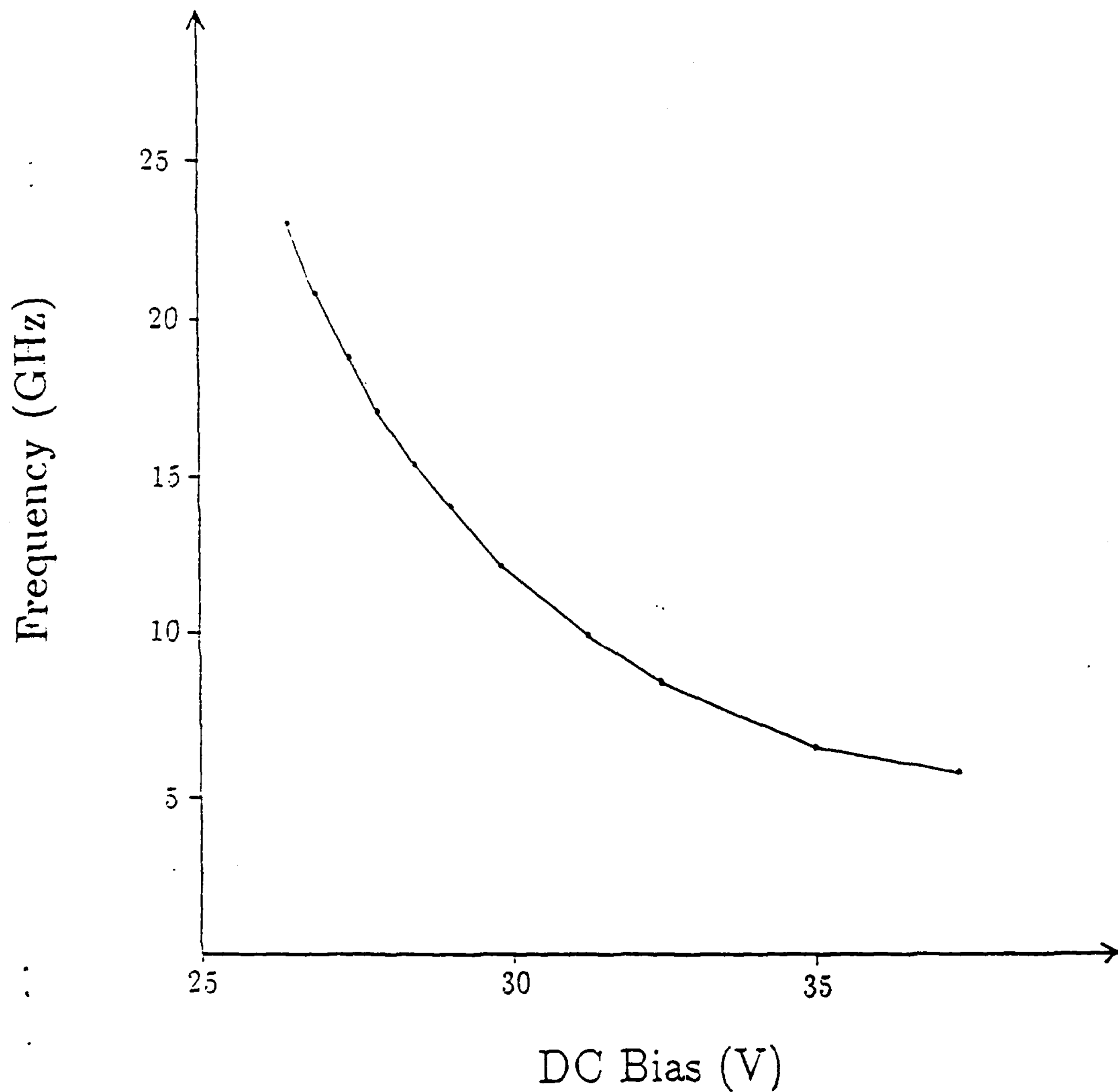


Fig. 4 The output frequency of the Gunn diode (Fig. 3) as a function DC bias voltage.

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