Photovoltaic Edge-Effect in Planar GaAs MESFETs

D. Abbott and K. Eshraghian *

Centre for GaAs VLSI Technology and Dept. of Electrical & Electronic Eng.
The University of Adelaide, SA 5005, Australia
email: dabbott@eleceng.adelaide.edu.au

ABSTRACT

A significant new internal gain effect, in planar MESFETs has been discovered which we call the "photovoltaic self-biasing edge-effect." The edge-effect can be exploited to attain up to a factor of ten improvement in detector photosensitivity.

1 INTRODUCTION

Under the conditions of photovoltaic self-biasing,[1] we have observed that there is a sharp increase in drain current when the transistor edges are illuminated.[2,3] This new internal gain edge effect is promising for enhanced photosensitivity, by a factor of ten, for lower frequency devices such as GaAs motion detectors,[4] XY array imagers,[5] optoelectronic neural nets[6] and X-ray detectors.[7] The edge-effect also has applications in device diagnostics and measurement – a new simple technique for determining SI substrate carrier diffusion length is demonstrated. Diffusion lengths of an order of magnitude lower than in silicon are observed – this is significant for improved spatial resolution in high definition television (HDTV) imagers. The edge-effect discovery is shown to be particularly suited to producing increased photosensitivity in a smart sensor array based on insect vision.

2 DISCUSSION

The drain current against laser XY position in Fig. 1, with no self-biasing, shows little photoresponse. With self-biasing enabled by a 10 MΩ gate resistor, Fig. 2 shows dramatic photocurrent peaks at the transistor edges. The smear-free contour plot in Fig. 3 shows the integrity of the laser scanning. It is observed that mesa structures do not display this effect. Furthermore the presence of a p-buffer layer is shown to diminish the gain – therefore planar devices with no p-buffer layer give rise to the greatest photocurrent gain. These results are consistent with the hypothesis that photocurrent in the substrate has access to the gate, at the transistor edges, creating an increased voltage drop across the gate resistor, thereby modulating the drain current. The simulated 3-D electric field mesh plot, Fig. 4, confirms interaction between the gate depletion region and channel/substrate depletion region, at the edge, that allows substrate photocurrent to flow into the gate. This is the first time that such interaction has been experimentally demonstrated. The practical applications are exciting as photosensitivity is increased by a factor of ten, and this can be exploited by appropriate design layout. In conclusion, we believe this gain effect is best exploited in our motion detector, based on insect vision principles, as it uses coarsely thresholded signals – whereas conventional imaging applications are sensitive to fixed-pattern noise (fpn).

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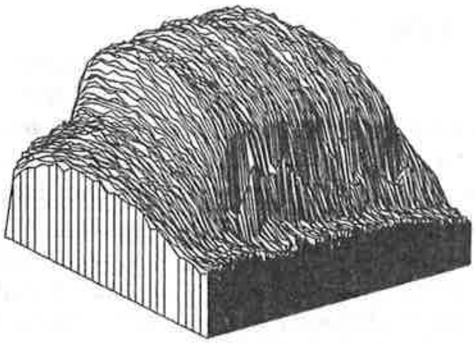

Figure 1: Measured MESFET drain current response (z-axis) to 2-D laser scan, max. current 3.7mA. No gate resistor.

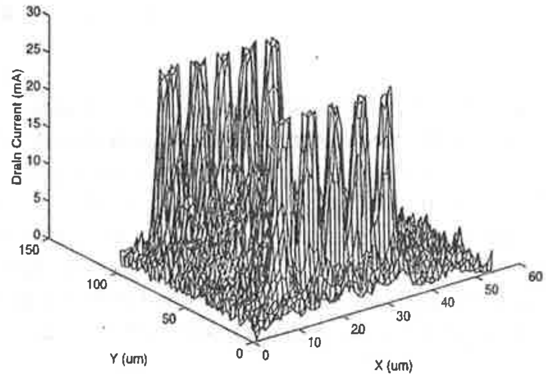

Figure 2: Measured MESFET drain current response (z-axis) to 2-D laser scan, max. current 29mA. With 10MΩ gate resistor. 3-D plot.

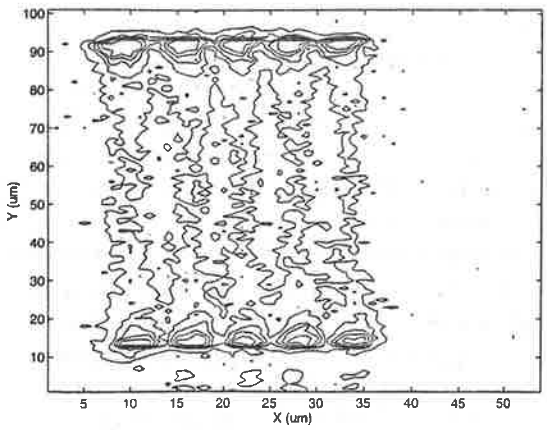

Figure 3: Measured MESFET drain current response (z-axis) to 2-D laser scan, max. current 29mA. With 10MΩ gate resistor. Contour plot.

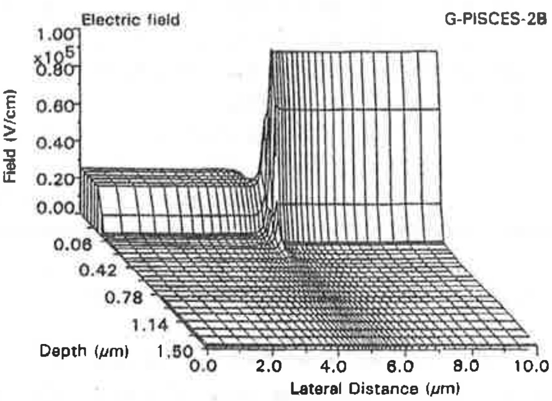

Figure 4: 3-D mesh plot of electric field (simulated). Gate on active region is on the right. Gate overhang on silicon nitride is on the left. Bulk is in the foreground and the surface is in the background.

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