

Chapter 7. High-Frequency InAlAs/InGaAs Metal-Insulator-Doped Semiconductor Field-Effect Transistors (MIDFET's) for Telecommunications

Sponsor

Joint Services Electronics Program (Contracts DAAL03-86-K-0002 and DAAL03-89-C-0001)

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The goals of this new project at RLE are to design, fabricate, test, and model submicron InAlAs/InGaAs Heterostructure Field-Effect Transistors (HFET's) on InP. In particular, we are pursuing device structures in which the InAlAs gate material is undoped but the InGaAs channel is thin and heavily doped. We call this new device a MIDFET, for Metal-Insulator Doped-channel Field-Effect Transistor.

There are many advantages of this device over MODFET's that stem from the lack of dopant impurities in the InAlAs gate insulator:

1. Absence of DX centers and their deleterious effects: persistent photoconductivity, low-temperature current collapse, etc.
2. Absence of transconductance and current-gain cut-off frequency collapse at large gate bias.
3. Improved breakdown voltage.

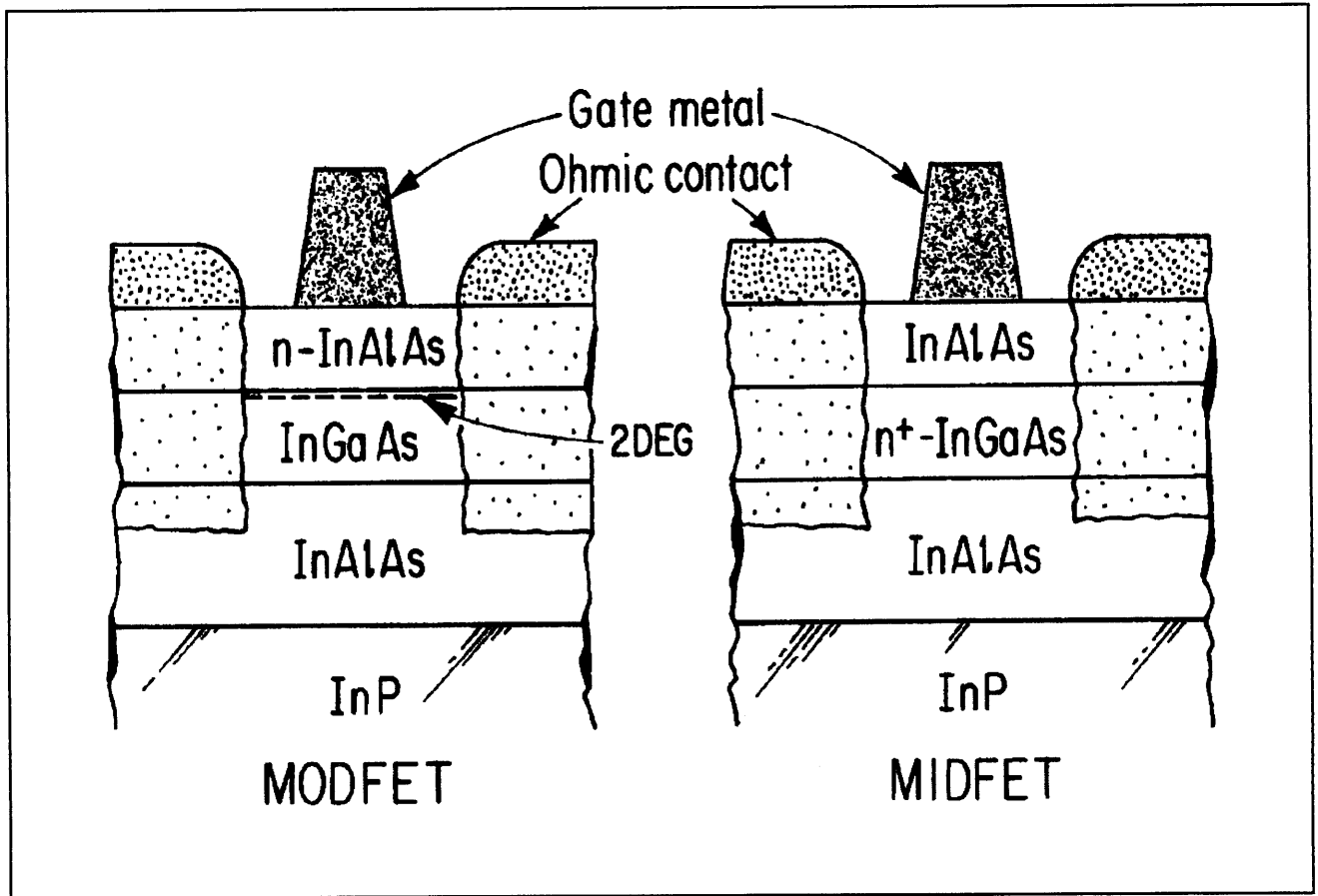
Due to these merits over MODFET's, MIDFET's may arise as the device of choice for a number of applications: microwave power amplifiers, optoelectronic integrated circuits on InP, and ultra high-speed logic.

Work to date has concentrated on the growth of high-quality InAlAs and InGaAs epitaxial

layers on InP by molecular-beam epitaxy. We have consistently achieved lattice-matching conditions (mismatch smaller than 0.1 percent) over extended periods of time for both ternaries. We have carried out Si doping-calibration growths of InGaAs in the $10^{17} - 10^{19} \text{ cm}^{-3}$ doping range. We have also grown a number of exploratory device structures that will be processed very soon.

In order to obtain fast turn-around calibration of doping of InGaAs we have refitted an existing vacuum chamber into an ohmic contact alloying oven. This permits the fabrication of Sn/In ohmic contacts on van der Pauw test samples of InGaAs in a very short time. We have also built a special sample holder for the van der Pauw samples that does not require bonding. Simple pressure contacts hold the sample in place and provide electrical contacts. This holder has considerably reduced sample mounting time.

Finally, we have designed and fabricated a five-level device mask set that incorporates a large number of test devices. We have several field-effect transistors with gate lengths between 1 and 50 microns with three different gate orientations with respect to the flat of the wafer: 0, 45, and 90 degrees. We have incorporated microwave transistors with gate lengths between 1 and 5 microns in two orientations: 0 and 90 degrees. A Transmission-Line Model (TLM) structure is



intended for measurement of parasitic resistances. Simple Hall and gated-Hall test patterns will measure the carrier and mobility profiles in the channel. We also have side-gating test devices, gate-leakage current test patterns, and several structures for measuring the sheet resistance of the various layers involved.

Publications and Conference Papers Presented

del Alamo, J., Eight invited contributions to *Properties of Silicon*, EMIS Datareviews Series No. 4. INSPEC, the Institute of Electrical Engineers, London: 1988.

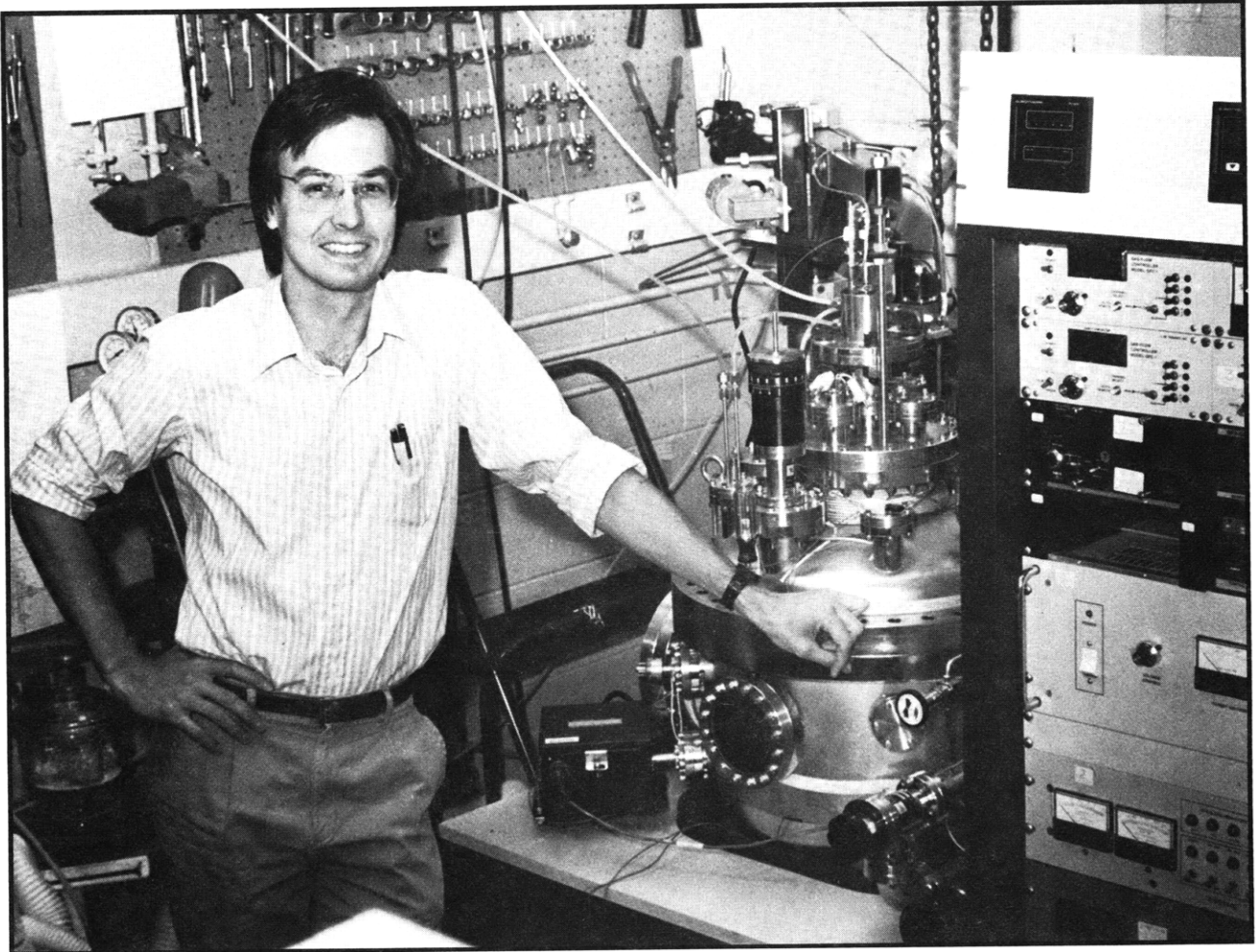
The titles of the datareviews are:

- 5.4 Electron mobility in n-type epitaxial Si, 142-143.
- 5.7 Minority carrier electron mobility in p-type Si, 145-146.

- 5.8 Minority carrier electron diffusion length in p-type Si, 147.
- 5.9 Minority carrier electron lifetime in p-type Si, 148-149.
- 6.3 Hole mobility in p-type epitaxial Si, 160-161.
- 6.4 Minority carrier hole mobility in n-type Si, 162-163.
- 6.5 Minority carrier hole diffusion length in n-type Si, 164-165.
- 6.6 Minority carrier hole lifetime in n-type Si, 166-167.

del Alamo, J., and T. Mizutani, "A Modulation-Doped Channel InAlAs/-InGaAs MIFET (Metal-Insulator-Doped Semiconductor FET)," Presented at 1988 Workshop on Compound Semiconductor Materials and Devices (WOCSEMMAD), Monterey, California, February 22-24, 1988.

- del Alamo, J., and T. Mizutani, "A Recessed-Gate InAlAs/n⁺-InGaAs MISFET," Presented at the 35th Spring Meeting of the Japan Society of Applied Physics, Tokyo, Japan, March 28-31, 1988. Abstract published in *Extended Abstracts of the Japan Society of Applied Physics* 1003 (1988).
- del Alamo, J., "High-Performance InAlAs-InGaAs MIS-type FET's Fabricated by MBE," Presented at the 3rd New England MBE Workshop, Cambridge, Massachusetts, April 19, 1988.
- del Alamo, J., and T. Mizutani, "An InAlAs/n⁺-InGaAs MISFET with a Modulation-Doped Channel," Presented at 46th Annual Device Research Conference, Boulder, Colorado, June 20-22, 1988. Abstract published in *IEEE Trans. Electron. Devices* 35(12):2441 (1988).
- del Alamo, J., and T. Mizutani, "An InAlAs/n⁺-InGaAs MISFET with a Modulation-Doped Channel," Presented at 49th Fall Meeting of the Japan Society of Applied Physics, Fukui, Japan, October 4-7, 1988. Abstract published in *Extended Abstracts of the Japan Society of Applied Physics* 940 (1988).
- del Alamo, J., and T. Mizutani, "A Recessed-Gate InAlAs/n⁺-InGaAs MISFET," Presented at the Symposium on Advances in Materials, Processing and Devices in III-V Compound Semiconductors of the Fall 1988 Materials Research Society Meeting, Boston, Massachusetts, November 28-30, 1988. To be published in *Symposium Proceedings* (1989).
- del Alamo, J., and T. Mizutani, "AuGeNi Ohmic Contacts to InP for FET Applications," *Solid-State Electron.* 31 (11):1635-1639 (1988).
- del Alamo, J., and T. Mizutani, "Bias Dependence of f_T and f_{max} in an InAlAs/n⁺-InGaAs MISFET," *IEEE Electron Device Lett.* EDL-9 (12):654-656 (1988).
- Tomizawa, M., T. Mizutani, and J. del Alamo, "2D Analysis for Modulation-Doped Channel MISFET," Presented at 49th Fall Meeting of the Japan Society of Applied Physics, Fukui, Japan, October 4-7, 1988. Abstract published in *Extended Abstracts of the Japan Society of Applied Physics* 940 (1988).
- Wagner, J., and J. del Alamo, "Band Gap Narrowing in Heavily Doped Silicon: A Comparison of Optical and Electrical Data," *J. Appl. Phys.* 63 (2):425-429 (1988).



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