Process Oriented MESFET Models for Transistor Design using ATLAS and ATHENA/FLASH

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Introduction

Microwave MESFETS (Metal Semiconductor Field Effect Transistors) are widely used in contemporary designs intended to operate in the frequency range 1 to 20 GHz. These devices are fabricated from n-type GaAs (epitaxially grown or using ion-implanted material) and have sub-micron gate lengths, usually in shallow recesses. Two-dimensional modeling has been used at Leeds to develop a process-oriented design philosophy. The Silvaco ATLAS software has been used to investigate the sensitivity to the fabrication process and implantation profile of highly doped ion-implanted structures. The compatibility of the ATHENA/Flash and ATLAS provided an ideal platform to perform this investigation.

Initially the ion-implantation data given from the device fabricator is converted using ATHENA/Flash into a net doping profile. This doping profile is then implemented in ATLAS along with the device dimensions to give a full two-dimensional representation of the FET. ATLAS can then be used to model the device, the physical parameters being available in both x and y dimensions. The DC I/V characteristics can also be extracted.

Modeling the Ion-Implants using FLASH

The full two-dimensional model requires the net doping profile for the device. This can easily be achieved by simulating the ion-implantation procedure using Flash. This package allows the user to specify the initial material and the type of implant. For the particular device being modeled there were two implants, an acceptor and a donor. Both of these implants were specified by the type of material, the concentration and the ionization energy. Flash also allows the angle of penetration of the implant to be taken into account. For this example it was assumed that the implant entered the material perpendicular to the surface. Silvaco's graphics program Tonyplot was used to display the results of the ion-implant process. Donor and acceptor implant profiles are shown in Figure 1.

The resulting doping profile was used with both the two-dimensional simulator, ATLAS, to investigate the operation and physics of the device.

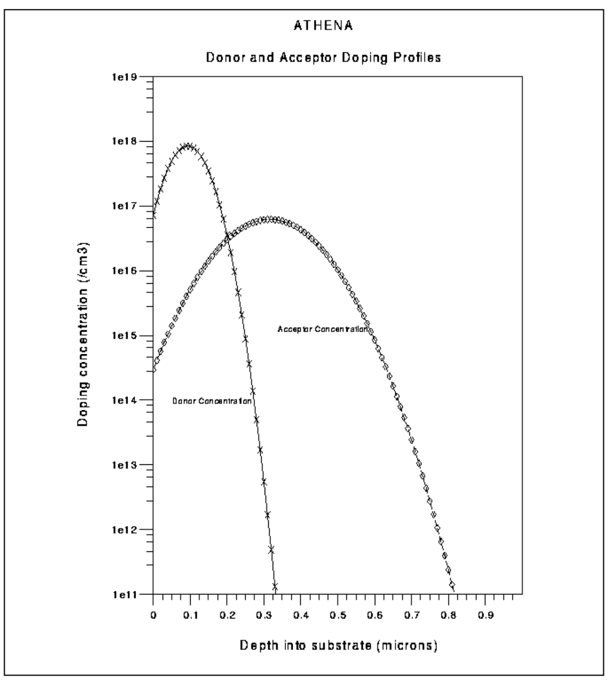

Figure 1. Donor and Acceptor profiles from Flash.

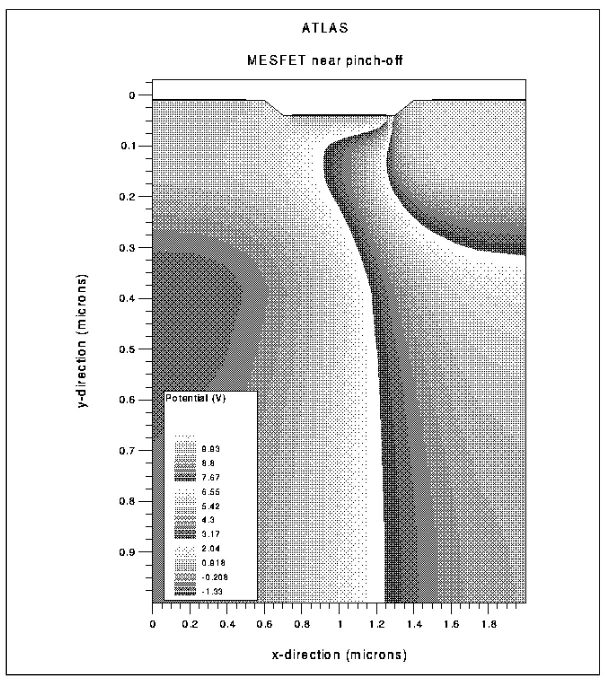

Figure 3. Potential contour - MESFET near pich off.

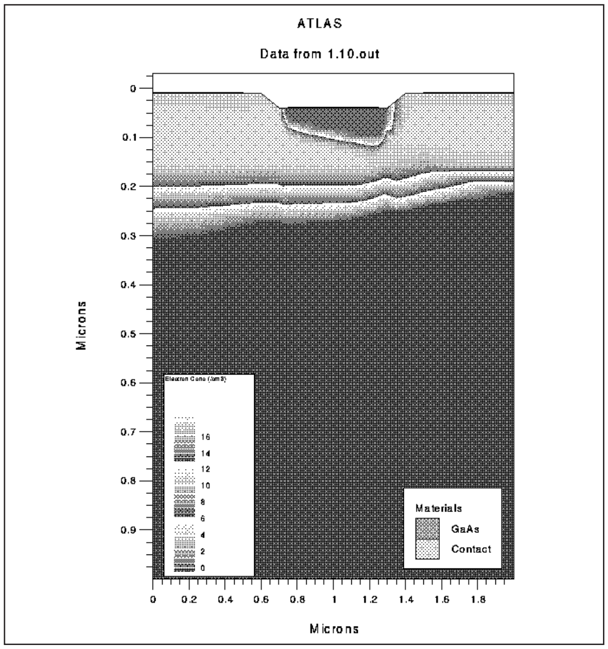

Figure 2. Electron concentration showing gate depletion region.

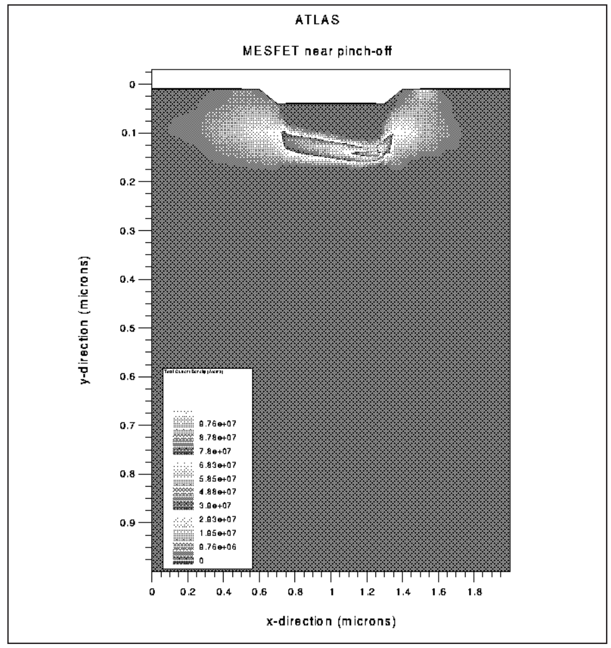

Figure 4. Total current density showing channel bounded by p-type doping layer.

ATLAS Results

The overall device dimensions were entered entered in to SILVACO using the DevEdit structure editor, along with the doping profile obtained above and a shallow recess. DeckBuild was used to control the order of the two-dimensional simulation, again the output being shown graphically using TonyPlot. Shown in Figures 2 to 4, are some of the cross-sectional physical results obtained from ATLAS.

The graph of electron concentration, Figure 2, shows quite clearly the device close to pinch-off, in this case a potential of -3 volts was applied to the gate contact. It is also apparent that the buried p-type layer (from the acceptor ion-implant) provides enhanced electron containment, increasing the output resistance and minimizing short-gate effects. This effect is also displayed in Figure 3, again near to pinch-off, where the applied potential is concentrated in the highly doped n region under the drain, dropping off rapidly with depth into the substrate. Figure 4, shows the total current density, with the peak being visible in the area between the gate depletion region and the top of the p-type layer (the region of maximum channel restriction).

The results of this work have been used to support the development of CAD-oriented quasi-two-dimensional MESFET models,[1], especially to support the development of nonlinear CAD, (for example microwave oscillator design) [2].

Conclusions

It is vital to fully understand how the physics of the device influence the operation of today's microwave transistors. Information obtained from two-dimensional numerical modeling, using ATLAS and ATHENA/ FLASH allow new CAD models and optimal designs of devices to be achieved. In this work an ion-implanted MESFET device has been modeled and the impact of the shallow recess and doping profile fully assessed.

References

[1] C.M. Snowden and R.R. Pantoja. Quasi-Two_dimensional MESFET Simulations for CAD. IEEE Trans. Electron Dev., ED-36(9):1564-1574, 1989.

[2] A.J. Panks, M.J Howes and C.M Snowden. The Synthesis of Micro-wave and MM-wave Transistor Oscillators Based on Physical Mod-eling. Proc. 25th European Microwave Conf., pages 1230-1234, 1995.