Increasing Transconductance of Indium-Gallium-Arsenide Fin Field-Effect Transistors after Sequential Annealing

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Introduction

- Transistors are semiconductor devices capable of acting as electrical switches.
- FinFETs are a special kind of transistors that have a 3D structure which allows for better switching control.
- Transistors are usually evaluated on their current-voltage (I-V) characteristics.
- Conductance is the derivative of the drain current with respect to gate voltage.
- InGaAs is a III-V semiconductor material with better electrical properties than the traditional Si used for transistors.
- The devices were subjected to sequential annealing at 250⁰, 300⁰ and 350⁰C to test performance.

Objectives and Motivation

- Obtain a deeper understanding of FinFET performance.
- Obtain I-V characteristics of the devices.
- Study the device performance before and after sequential annealing and see how it changes.
- Design transistors capable of operating at lower voltage to reduce device power consumption and increase efficiency.

Methods

- The sample studied included 1600+ transistors across 16 dies, but for deeper study, the focus was on the fourth column, 400 devices.
- Each die included DC, MM, RF, LA and SF devices.
- Sequential annealing was only done for one die, 100 devices, of which only 37 were working devices.
- The devices under study were studied in a microscope probe station and measured using the B1500 semiconductor device analyzer.
- This setup is used to measure the I-V characteristics of the devices.
- Data gathered were analyzed to determine which devices were worthy of further study.

Key Findings

- The devices were annealed to improve their performance behavior under different conditions.
- There was no change in single-fin transistor transconductance with sequential annealing suggesting it improved the extrinsic part of the device with negligible effect on the MOS interface.
- In the future, we would like to study a wider array of devices to further understand their performance under different conditions.

Conclusions and Future Work

- When subjecting these devices to sequential annealing their transconductance significantly improved.
- There was no increase in single-fin transistor transconductance with sequential annealing suggesting it improved the extrinsic part of the device with negligible effect on the MOS interface.
- In the future, we would like to study a wider array of devices to further understand their performance under different conditions.

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Table 1: $S_{ox}$ Comparison

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<thead>
<tr>
<th>Temperature (°C)</th>
<th>$S_{ox}$ (μm²/V·s)</th>
<th>$S_{min}$ (μm²/V·s)</th>
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Figure 1: MOSFET circuit symbol

Figure 2: Closed circuit symbol

Figure 3: Open circuit symbol

Figure 4: MOSFET Schematic

Figure 5: FinFET Schematic

Figure 6: Typical I-V characteristics for FETs with $W/L = 9$ nm

Figure 7: Sample under study

Figure 8: Microscope probe station

Figure 9: Under-the-microscope view of sample

Figure 10: Under-the-microscope view probing the sample

Figure 11: Annealing the sample

Figure 12: I-V Characteristics of Wide Fin Devices for Different Annealing Temperatures

Figure 13: $g_m$ Characteristics of Wide Fin Devices for Different Annealing Temperature

Figure 14: I-V Characteristics of Narrow Fin Device

Figure 15: $g_m$ Characteristics of Narrow Fin Devices for Different Annealing Temperatures

Figure 16: I-V Characteristics of Single Fin Device

Figure 17: $g_m$ Characteristics of Single Fin Devices for Different Annealing Temperatures

Maximum $g_m$ as a function of Sequential Annealing Temperature

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