Model created in COMSOL Multiphysics 6.4

DC Characteristics of a MESFET

This model compares the current–voltage characteristics of a MESFET using the majority carrier only formulation.

Introduction

MOSFETs and MESFETs (metal–semiconductor field-effect transistor) work very similarly. In a MESFET, the gate forms a rectifying junction that controls the opening of the channel by varying the depletion width of the junction.

In this model we simulate the response of a n-doped GaAs MESFET to different drain and gate voltages. For a n-doped material the electron concentration is expected to be orders of magnitude larger than the hole concentration. Accordingly, it is possible to use the majority carrier option to compute an accurate solution with less degrees of freedom then it would normally be needed using the electrons and holes formulation.

Model Definition

The model compares the effect of the carrier formulation on the solution of a 2D MESFET biased with different gate (0, 1, and 2 V) and drain (from 0 to 10 V) voltages.

The geometry is composed of a block of 4 by 0.5 μm. The Schottky contact (gate) has a length of 1 μm. The source (top left) and drain (top right) have both a length of 0.5 μm. Figure 1 shows the model's geometry.

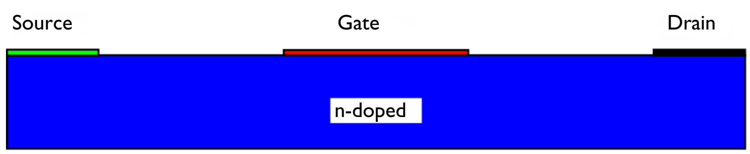

Figure 1: Geometry of the modeled MESFET.

Results and Discussion

Figure 2 plots the drain current as a function of the drain voltage for both studies (electrons and holes and majority carrier only). The result is identical. Note that the number of degrees of freedom used for the first study (electrons and holes) is 1.5 times larger than the number of degrees of freedom used for the second study (majority carrier only).

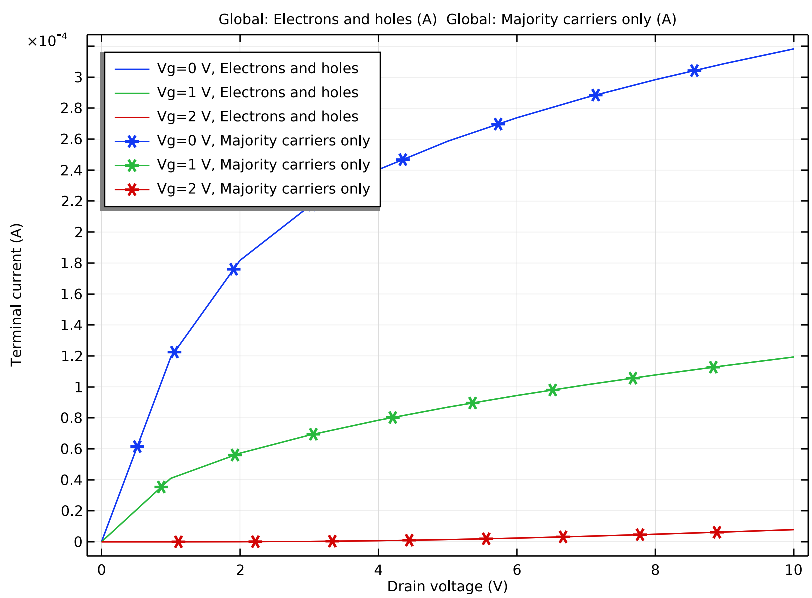

Figure 2: Drain current as a function of the drain voltage for the electrons and holes and for the majority carrier only (asterisk).

Application Library path: `Semiconductor_Module/Transistors/mesfet`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **2D**.

2 In the **Select Physics** tree, select **Semiconductor** > **Semiconductor (semi)**.

3 Click **Add**.

4 Click **Done**.

GLOBAL DEFINITIONS

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
L	1[um]	1E-6 m	Gate length
Wd	4[um]	4E-6 m	Device width
Hd	0.5[um]	5E-7 m	Device height
Ws	1[um]	1E-6 m	Source width
Wdd	1[um]	1E-6 m	Drain width
Vg	0[V]	0 V	Gate voltage
Vd	0[V]	0 V	Drain voltage
Vs	0[V]	0 V	Source voltage
Nd	1e16[1/cm^3]	1E22 1/m³	Doping

GEOMETRY 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.

2 In the **Settings** window for **Geometry**, locate the **Units** section.

3 From the **Length unit** list, choose **µm**.

Rectangle 1 (r1)

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `Wd`.

4 In the **Height** text field, type `Hd`.

5 Locate the **Position** section. In the **x** text field, type `-Wd/2`.

Add points to define the source, drain and gate contacts.

Point 1 (pt1)

1 In the **Geometry** toolbar, click **Point**.

2 In the **Settings** window for **Point**, locate the **Point** section.

3 In the **x** text field, type `-Wd/2+Ws/2 -L/2 L/2 Wd/2-Ws/2`.

4 In the **y** text field, type `Hd Hd Hd Hd`.

5 Click **Build All Objects**.

ADD MATERIAL

1 In the **Materials** toolbar, click **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Semiconductors** > **GaAs - Gallium Arsenide**.

4 Click the **Add to Component** button in the window toolbar.

5 In the **Materials** toolbar, click **Add Material** to close the **Add Material** window.

SEMICONDUCTOR (SEMI)

Metal Contact 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Metal Contact**.

2 In the **Settings** window for **Metal Contact**, locate the **Contact Type** section.

3 From the **Type** list, choose **Ideal Schottky**.

4 Select Boundary 5 only.

5 Locate the **Terminal** section. In the V_0 text field, type `-Vg`.

Metal Contact 2

1 In the **Physics** toolbar, click **Boundaries** and choose **Metal Contact**.

2 Select Boundary 3 only.

3 In the **Settings** window for **Metal Contact**, locate the **Terminal** section.

4 In the V_0 text field, type `Vs`.

Metal Contact 3

1 In the **Physics** toolbar, click **Boundaries** and choose **Metal Contact**.

2 Select Boundary 7 only.

3 In the **Settings** window for **Metal Contact**, locate the **Terminal** section.

4 In the V_0 text field, type `Vd`.

Analytic Doping Model 1

1 In the **Physics** toolbar, click **Domains** and choose **Analytic Doping Model**.

2 Select Domain 1 only.

3 In the **Settings** window for **Analytic Doping Model**, locate the **Impurity** section.

4 From the **Impurity type** list, choose **Donor doping (n-type)**.

5 In the N_{D0} text field, type `Nd`.

Trap-Assisted Recombination 1

1 In the **Physics** toolbar, click **Domains** and choose **Trap-Assisted Recombination**.

2 Select Domain 1 only.

3 In the **Settings** window for **Trap-Assisted Recombination**, locate the **Shockley–Read–Hall Recombination** section.

4 From the τ_n list, choose **User defined**. From the τ_p list, choose **User defined**. In the **Model Builder** window, right-click **Semiconductor (semi)** and choose **Copy**.

SEMICONDUCTOR 2 (SEMI2)

1 In the **Model Builder** window, right-click **Component 1 (comp1)** and choose **Paste Semiconductor**.

2 In the **Messages from Paste** dialog, click **OK**.

3 In the **Settings** window for **Semiconductor**, locate the **Model Properties** section.

4 From the **Solution** list, choose **Majority carriers only**.

Adjust the mesh slightly.

MESH 1

In the **Model Builder** window, under **Component 1 (comp1)** right-click **Mesh 1** and choose **Edit Physics-Induced Sequence**.

Size 2

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Mesh 1** click **Size 2**.

2 In the **Settings** window for **Size**, locate the **Element Size** section.

3 From the **Predefined** list, choose **Finer**.

4 Click **Build All**.

ADD STUDY

1 In the **Home** toolbar, click **Add Study** to open the **Add Study** window.

2 Go to the **Add Study** window.

3 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies** > **Stationary**.

4 Click the **Add Study** button in the window toolbar.

5 In the **Home** toolbar, click **Add Study** to close the **Add Study** window.

STUDY 1

Step 1: Stationary

1 In the **Settings** window for **Stationary**, locate the **Physics and Variables Selection** section.

2 In the **Solve for** column of the table, under **Component 1 (comp1)**, clear the checkbox for **Semiconductor 2 (semi2)**.

Set up an auxiliary continuation sweep for the ’Vd’ parameter.

3 Click to expand the **Study Extensions** section. Select the **Auxiliary sweep** checkbox.

4 Click **Add**.

5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)		V

6 Click **Add**.

7 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)	`0 1 2`	V
Vd (Drain voltage)	`range(0,1,10)`	V

8 From the **Sweep type** list, choose **All combinations**.

9 From the **Reuse solution from previous step** list, choose **Auto**.

10 In the **Study** toolbar, click **Compute**.

RESULTS

Net Dopant Concentration (semi)

The model has a uniform n-doping therefore, we remove the generated default plot, Net Dopant Concentration.

1 In the **Model Builder** window, under **Results** right-click **Net Dopant Concentration (semi)** and choose **Delete**.

Drain current as a function of drain voltage

1 In the **Results** toolbar, click **1D Plot Group**.

2 In the **Settings** window for **1D Plot Group**, type `Drain current as a function of drain voltage` in the **Label** text field.

3 Locate the **Legend** section. From the **Position** list, choose **Upper left**.

Global 1

1 Right-click **Drain current as a function of drain voltage** and choose **Global**.

2 In the **Settings** window for **Global**, click **Replace Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1)** > **Semiconductor** > **Terminals** > **semi.I0_3 - Terminal current - A**.

3 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
semi.I0_3	A	Electrons and holes

4 In the **Drain current as a function of drain voltage** toolbar, click **Plot**.

ADD STUDY

1 In the **Home** toolbar, click **Add Study** to open the **Add Study** window.

2 Go to the **Add Study** window.

3 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies** > **Stationary**.

4 Click the **Add Study** button in the window toolbar.

5 In the **Home** toolbar, click **Add Study** to close the **Add Study** window.

STUDY 2

Step 1: Stationary

1 In the **Settings** window for **Stationary**, locate the **Physics and Variables Selection** section.

2 In the **Solve for** column of the table, under **Component 1 (comp1)**, clear the checkbox for **Semiconductor (semi)**.

3 Locate the **Study Extensions** section. Select the **Auxiliary sweep** checkbox.

4 Click **Add**.

5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)		V

6 Click **Add**.

7 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)	0 1 2	V
Vd (Drain voltage)	range(0,1,10)	V

8 From the **Sweep type** list, choose **All combinations**.

9 From the **Reuse solution from previous step** list, choose **Auto**.

10 In the **Study** toolbar, click **Compute**.

RESULTS

Net Dopant Concentration (semi2)

The model has a uniform n-doping therefore, we remove the generated default plot, Net Dopant Concentration.

1 In the **Model Builder** window, under **Results** right-click **Net Dopant Concentration (semi2)** and choose **Delete**.

Global 2

1 In the **Model Builder** window, under **Results > Drain current as a function of drain voltage** right-click **Global 1** and choose **Duplicate**.

2 In the **Settings** window for **Global**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 2/Solution 2 (sol2)**.

4 Click **Replace Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Semiconductor 2 > Terminals > semi2.I0_3 - Terminal current - A**.

5 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
semi2.I0_3	A	Majority carriers only

6 Click to expand the **Coloring and Style** section. Find the **Line markers** subsection. From the **Marker** list, choose **Asterisk**.

7 From the **Positioning** list, choose **Interpolated**.

8 Click to expand the **Coloring and Style** section. From the **Color** list, choose **Cycle (reset)**.

Drain current as a function of drain voltage

1 In the **Model Builder** window, click **Drain current as a function of drain voltage**.

2 In the **Settings** window for **1D Plot Group**, locate the **Plot Settings** section.

3 Select the **x-axis label** checkbox. In the associated text field, type `Drain voltage (V)`.

4 Select the **y-axis label** checkbox. In the associated text field, type `Terminal current (A)`.

5 In the **Drain current as a function of drain voltage** toolbar, click **Plot**.