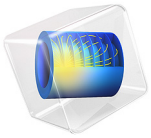

Model created in COMSOL Multiphysics 6.4

Fin Field-Effect Transistor

Introduction

A Fin Field-Effect Transistor, for short FinFET, is an advanced type of Field-Effect Transistor in a 3D structure. The name comes from the fin-shaped structure of the channel above the substrate. The gate electrode is placed around the channel on three sides, offering several advantages over planar structures. These include better control over current flow throughout the channel, lower leakage currents, and faster switching times. FinFETs are widely used in various applications, such as high-performance computing, biomedical electronics, and home electronic devices.

This example shows how to model the 3D structure of a FinFET.

Model Definition

Figure 1 shows the model geometry, indicating the source, drain, and gate electrodes. The model configuration is defined as follows: source and drain electrodes are placed on the two sides of the device and the gate electrode surrounds the channel area. The dimensions of the device are 3 μm, 0.7 μm, and 0.7 μm in width, depth, and height, respectively.

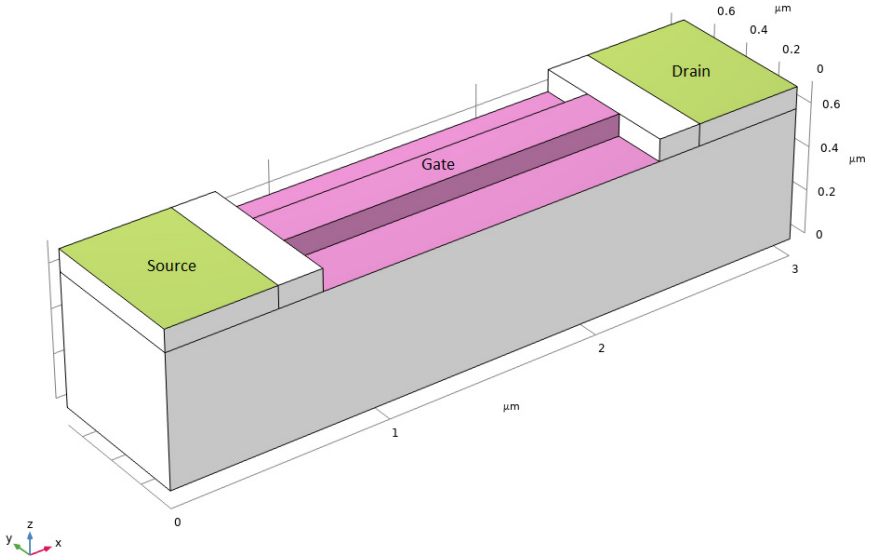

Figure 1: Model geometry showing the source, drain, and gate electrodes.

The procedure of the implementation is described in detail in the Modeling Instructions section.

Figure 2 shows the drain current versus gate voltage curves for different values of the drain voltage.

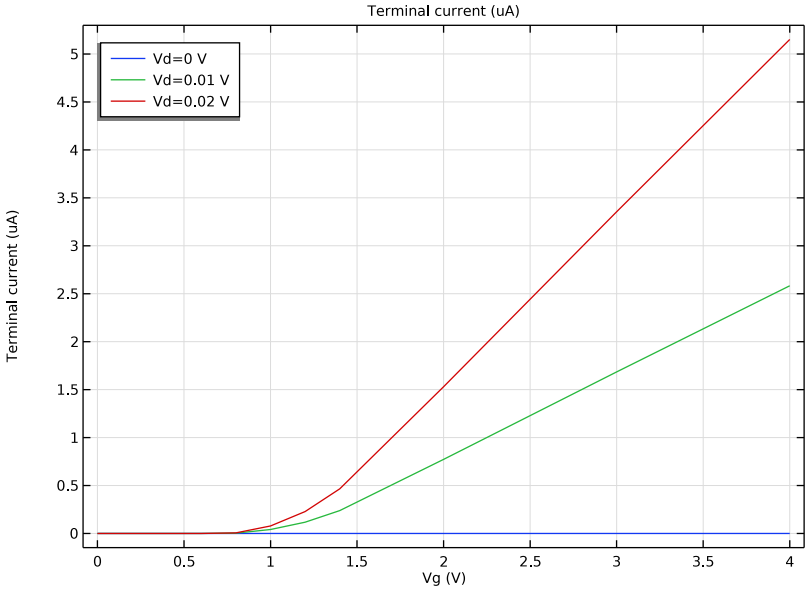

Figure 2: Drain current versus gate voltage for fixed drain voltage.

Figure 3 shows the drain current versus drain voltage for fixed gate voltages of 2, 3, and 4 V.

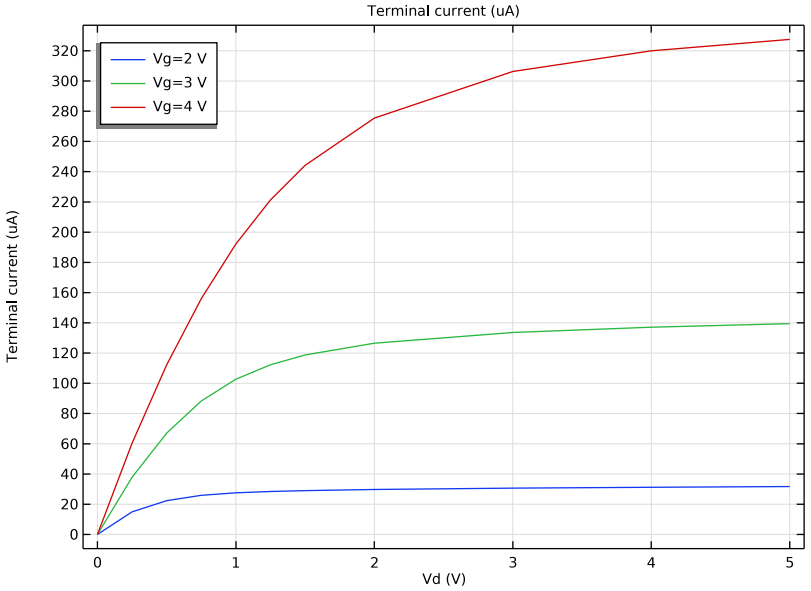

Figure 3: Drain current versus drain voltage curve.

Application Library path: `Semiconductor_Module/Transistors/finfet`

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 **3D**.

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

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies** > **Stationary**.

6 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
Vd	10[mV]	0.01 V	Drain voltage
Vg	2[V]	2 V	Gate voltage
w_finfet	3[um]	3E-6 m	FinFET width
d_finfet	0.7[um]	7E-7 m	FinFET depth
h_finfet	0.7[um]	7E-7 m	FinFET height
h_gate	0.1[um]	1E-7 m	Gate height
w_source	0.5[um]	5E-7 m	Source width
w_drain	0.5[um]	5E-7 m	Drain width
w_gate	1.6[um]	1.6E-6 m	Gate width
w_ins	(w_finfet-w_gate-w_source-w_drain)/2	2E-7 m	Insulator width
d_channel	0.2[um]	2E-7 m	Channel depth

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**.

Block 1 (blk1)

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

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

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

4 In the **Depth** text field, type `d_finfet`.

5 In the **Height** text field, type `h_finfet`.

Block 2 (blk2)

1. Right-click **Block 1 (blk1)** and choose **Duplicate**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.
3. In the **Width** text field, type `w_source`.
4. In the **Height** text field, type `h_gate`.
5. Locate the **Position** section. In the **z** text field, type `h_finfet-h_gate`.

Block 3 (blk3)

1. Right-click **Block 2 (blk2)** and choose **Duplicate**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.
3. In the **Width** text field, type `w_ins`.
4. Locate the **Position** section. In the **x** text field, type `w_source`.

Block 4 (blk4)

1. Right-click **Block 3 (blk3)** and choose **Duplicate**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.
3. In the **Width** text field, type `w_gate`.
4. In the **Depth** text field, type `d_channel`.
5. Locate the **Position** section. In the **x** text field, type `w_source+w_ins`.
6. In the **y** text field, type `(d_finfet-d_channel)/2`.

Block 5 (blk5)

1. Right-click **Block 4 (blk4)** and choose **Duplicate**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.
3. In the **Width** text field, type `w_ins`.
4. In the **Depth** text field, type `d_finfet`.
5. Locate the **Position** section. In the **x** text field, type `w_source+w_ins+w_gate`.
6. In the **y** text field, type `0`.

Block 6 (blk6)

1. Right-click **Block 5 (blk5)** and choose **Duplicate**.
2. In the **Settings** window for **Block**, locate the **Size and Shape** section.
3. In the **Width** text field, type `w_drain`.
4. Locate the **Position** section. In the **x** text field, type `w_source+2*w_ins+w_gate`.

Block 7 (blk7)

1 Right-click **Block 6 (blk6)** and choose **Duplicate**.

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

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

4 In the **Depth** text field, type `(d_finfet-d_channel)/2`.

5 Locate the **Position** section. In the **x** text field, type `w_source+w_ins`.

Block 8 (blk8)

1 Right-click **Block 7 (blk7)** and choose **Duplicate**.

2 In the **Settings** window for **Block**, locate the **Position** section.

3 In the **y** text field, type `(d_finfet+d_channel)/2`.

Difference 1 (dif1)

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Difference**.

2 Select the object **blk1** only.

3 In the **Settings** window for **Difference**, locate the **Difference** section.

4 Click to select the **Activate Selection** toggle button for **Objects to subtract**.

5 Select the objects **blk7** and **blk8** only.

6 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** > **Si - Silicon**.

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)

Background p Doping

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

2 In the **Settings** window for **Analytic Doping Model**, type `Background p Doping` in the **Label** text field.

3 Locate the **Domain Selection** section. From the **Selection** list, choose **All domains**.

4 Locate the **Impurity** section. In the N_{A0} text field, type `1e17[1/cm^3]`.

Source n Doping

1 Right-click **Background p Doping** and choose **Duplicate**.

2 In the **Settings** window for **Analytic Doping Model**, type `Source n Doping` in the **Label** text field.

3 Locate the **Distribution** section. From the list, choose **Box**.

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

5 In the N_{D0} text field, type `1e20[1/cm^3]`.

6 Locate the **Uniform Region** section. Specify the r_0 vector as

`0.6[um]`	Z

7 In the W text field, type `0.6[um]`.

8 In the D text field, type `0.7[um]`.

9 In the H text field, type `0.1[um]`.

10 Locate the **Profile** section. Select the **Specify different length scales for each direction** checkbox.

11 Specify the d_j vector as

`0.2[um]`	X
`0.2[um]`	Y
`0.25[um]`	Z

12 From the N_b list, choose **Acceptor concentration (semi/adm1)**.

Drain n Doping

1 Right-click **Source n Doping** and choose **Duplicate**.

2 In the **Settings** window for **Analytic Doping Model**, type `Drain n Doping` in the **Label** text field.

3 Locate the **Uniform Region** section. Specify the r_0 vector as

`2.4[um]`	X

Metal Contact Source

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

2 In the **Settings** window for **Metal Contact**, type `Metal Contact Source` in the **Label** text field.

3 Select Boundary 7 only.

Metal Contact Drain

1 Right-click **Metal Contact Source** and choose **Duplicate**.

2 In the **Settings** window for **Metal Contact**, type `Metal Contact Drain` in the **Label** text field.

3 Locate the **Boundary Selection** section. Click  **Clear Selection**.

4 Select Boundary 34 only.

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

Metal Contact Body

1 Right-click **Metal Contact Drain** and choose **Duplicate**.

2 In the **Settings** window for **Metal Contact**, type `Metal Contact Body` in the **Label** text field.

3 Locate the **Boundary Selection** section. Click  **Clear Selection**.

4 Select Boundary 3 only.

5 Locate the **Terminal** section. In the V_0 text field, type `0`.

Thin Insulator Gate 1

1 In the **Physics** toolbar, click  **Boundaries** and choose **Thin Insulator Gate**.

2 Select Boundaries 16, 18, 20, 22, and 23 only.

3 In the **Settings** window for **Thin Insulator Gate**, locate the **Terminal** section.

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

5 Locate the **Gate Contact** section. In the ε_{ins} text field, type `4.5`.

6 In the d_{ins} text field, type `30[nm]`.

Trap-Assisted Recombination 1

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

2 In the **Settings** window for **Trap-Assisted Recombination**, locate the **Domain Selection** section.

3 From the **Selection** list, choose **All domains**.

MESH 1

Free Triangular 1

1 In the **Mesh** toolbar, click  **More Generators** and choose **Free Triangular**.

2 Select Boundaries 7, 13, 16, 20, 23, 27, and 34 only.

Size

1 In the **Model Builder** window, click **Size**.

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

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

Swept 1

1 In the **Mesh** toolbar, click  **Swept**.

2 In the **Settings** window for **Swept**, locate the **Domain Selection** section.

3 From the **Geometric entity level** list, choose **Domain**.

4 Select Domains 2–6 only.

Distribution 1

1 Right-click **Swept 1** and choose **Distribution**.

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

3 From the **Distribution type** list, choose **Predefined**.

4 In the **Number of elements** text field, type `10`.

Swept 2

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Mesh 1** right-click **Swept 1** and choose **Duplicate**.

2 In the **Settings** window for **Swept**, locate the **Domain Selection** section.

3 Click  **Clear Selection**.

4 Select Domain 1 only.

Distribution 1

1 In the **Model Builder** window, expand the **Swept 2** node, then click **Distribution 1**.

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

3 In the **Number of elements** text field, type `20`.

4 In the **Element ratio** text field, type `0.1`.

5 Select the **Reverse direction** checkbox.

6 Click  **Build All**.

STUDY 1: VG SWEEP

1 In the **Model Builder** window, click **Study 1**.

2 In the **Settings** window for **Study**, type `Study 1: Vg Sweep` in the **Label** text field.

Step 1: Stationary

1 In the **Model Builder** window, under **Study 1: Vg Sweep** click **Step 1: Stationary**.

2 In the **Settings** window for **Stationary**, click to expand the **Study Extensions** section.

3 Select the **Auxiliary sweep** checkbox.

4 Click + **Add**.

5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vd (Drain voltage)	`range(0,0.01,0.02)`	V

6 Click + **Add**.

7 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)	`range(0,0.2,1.4) 2 3 4`	V

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

9 In the **Study** toolbar, click = **Compute**.

RESULTS

Id-Vg

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

2 In the **Settings** window for **1D Plot Group**, type `Id-Vg` in the **Label** text field.

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

Global 1

1 Right-click **Id-Vg** 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_2 - Terminal current - A**.

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

Expression	Unit	Description
`semi.I0_2`	uA	`Terminal current`

4 Click to expand the **Legends** section. Find the **Include** subsection. Clear the **Description** checkbox.

5 In the **Id-Vg** 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: VD SWEEP

1 In the **Settings** window for **Study**, type `Study 2: Vd Sweep` in the **Label** text field.

2 Locate the **Study Settings** section. Clear the **Generate default plots** checkbox.

Step 1: Stationary

1 In the **Model Builder** window, under **Study 2: Vd Sweep** click **Step 1: Stationary**.

2 In the **Settings** window for **Stationary**, click to expand the **Values of Dependent Variables** section.

3 Find the **Initial values of variables solved for** subsection. From the **Settings** list, choose **User controlled**.

4 From the **Method** list, choose **Solution**.

5 From the **Study** list, choose **Study 1: Vg Sweep, Stationary**.

6 From the **Parameter value (Vg (V),Vd (V))** list, choose **Manual**.

7 In the **Index** text field, type `9`.

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

9 Click **Add**.

10 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vg (Gate voltage)	`range(2,1,4)`	V

11 Click **Add**.

12 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
Vd (Drain voltage)	`range(0,0.25,1.5) 2 3 4 5`	V

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

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

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

RESULTS

Id-Vd

1 In the **Model Builder** window, right-click **Id-Vg** and choose **Duplicate**.

2 In the **Settings** window for **1D Plot Group**, type `Id-Vd` in the **Label** text field.

3 Locate the **Data** section. From the **Dataset** list, choose **Study 2: Vd Sweep/ Solution 2 (sol2)**.

4 In the **Id-Vd** toolbar, click **Plot**.