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Modeling PIN Photodiodes

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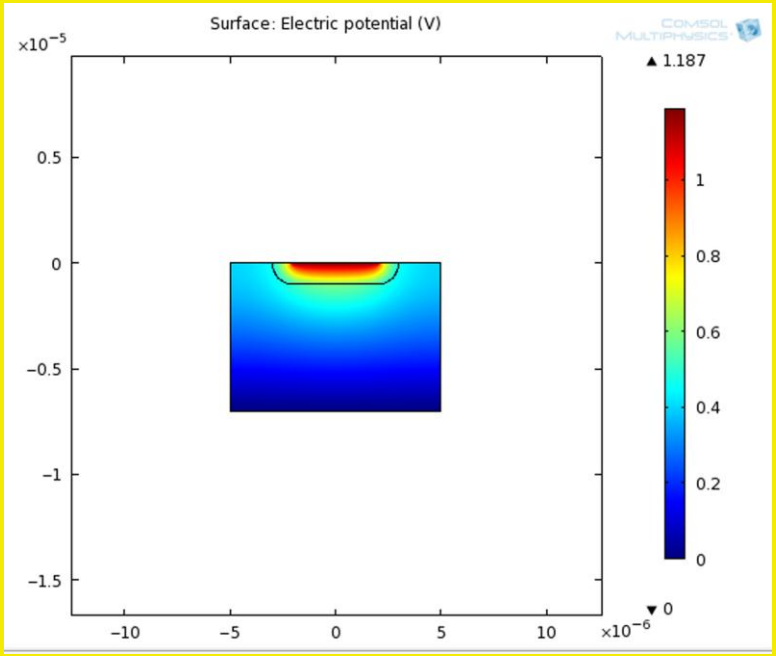
Pryor Knowledge Systems, Inc.

PIN Photodiode Modeling

This paper presents a new AC/DC Conduction Current Module Model of a PIN Photodiode using COMSOL Multiphysics 4.0a and SPICE



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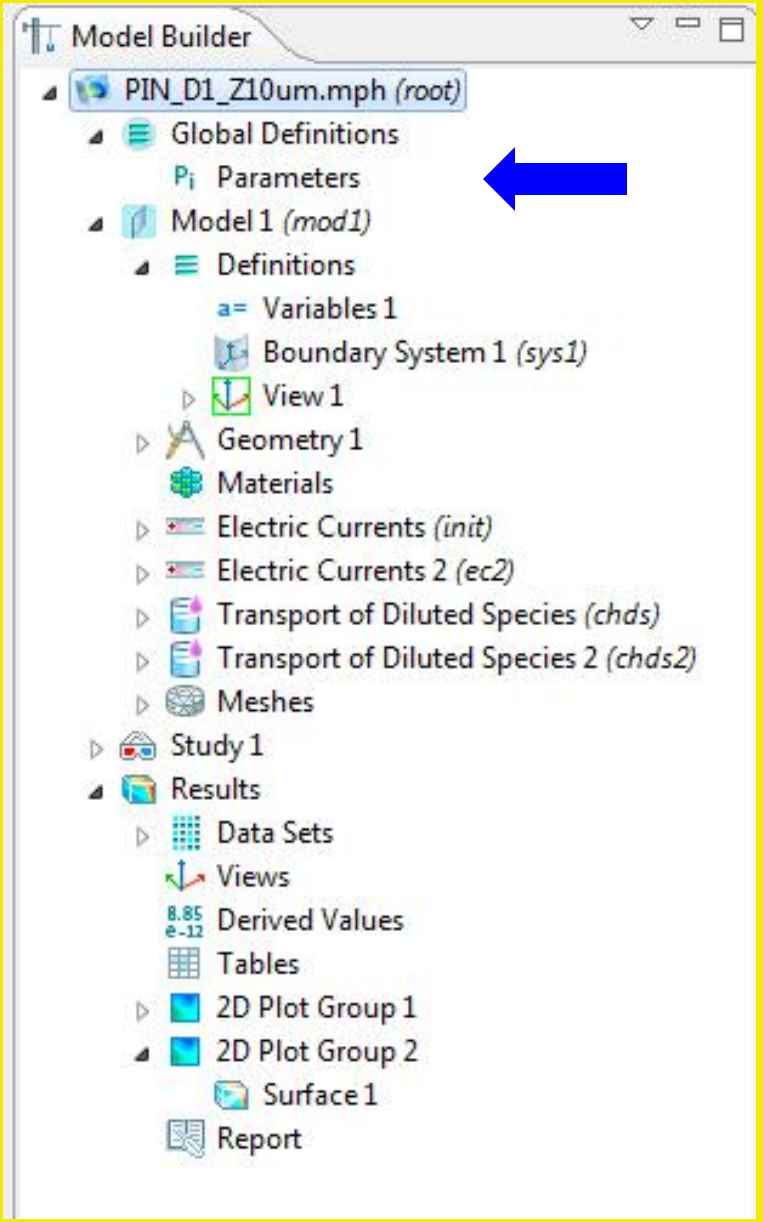
9. Light Generated Carrier Pairs (Electrons(-), Holes(+))

Building the PIN Photodiode Model

Model Builder Chart Model 1



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Building the PIN Photodiode Model

Parameters

Parameter	Value	Description
q	1.602e-19[C]	Elementary charge
T	300[K]	Room temperature
k	1.38e-23[J/K]	Boltzmann's constant
epsilonr	11.8	Rel. permittivity for Si
ni	1.46e10[1/cm^3]	Intrinsic concentration for Si
mun	800[cm^2/(V*s)]	Electron mobility for Si
mup	200[cm^2/(V*s)]	Hole mobility for Si
Dn	k*T/q*mun	Electron diffusivity
Dp	k*T/q*mup	Hole diffusivity
taun	0.1[us]	Electron life time
taup	0.1[us]	Hole life time
c	q/(k*T)	Reciprocal thermal voltage
y1	7[um]	Diode dimension
x1	10[um]	Diode dimension
ju	1[um]	Junction depth
ac	4[um]	Anode dimension
NApmax	1e17[1/cm^3]	Maximum p-type doping
NDn	1e15[1/cm^3]	Drift layer n-type doping
NDnmax	1e17[1/cm^3]	Maximum n-type doping
ch	ju/sqrt(log(NApmax/NDn))	Doping fall-off constant
Va	0[V]	Applied voltage
Vt	k*T/q	Thermal voltage
Vpsi0	0[V]	Initialization voltage

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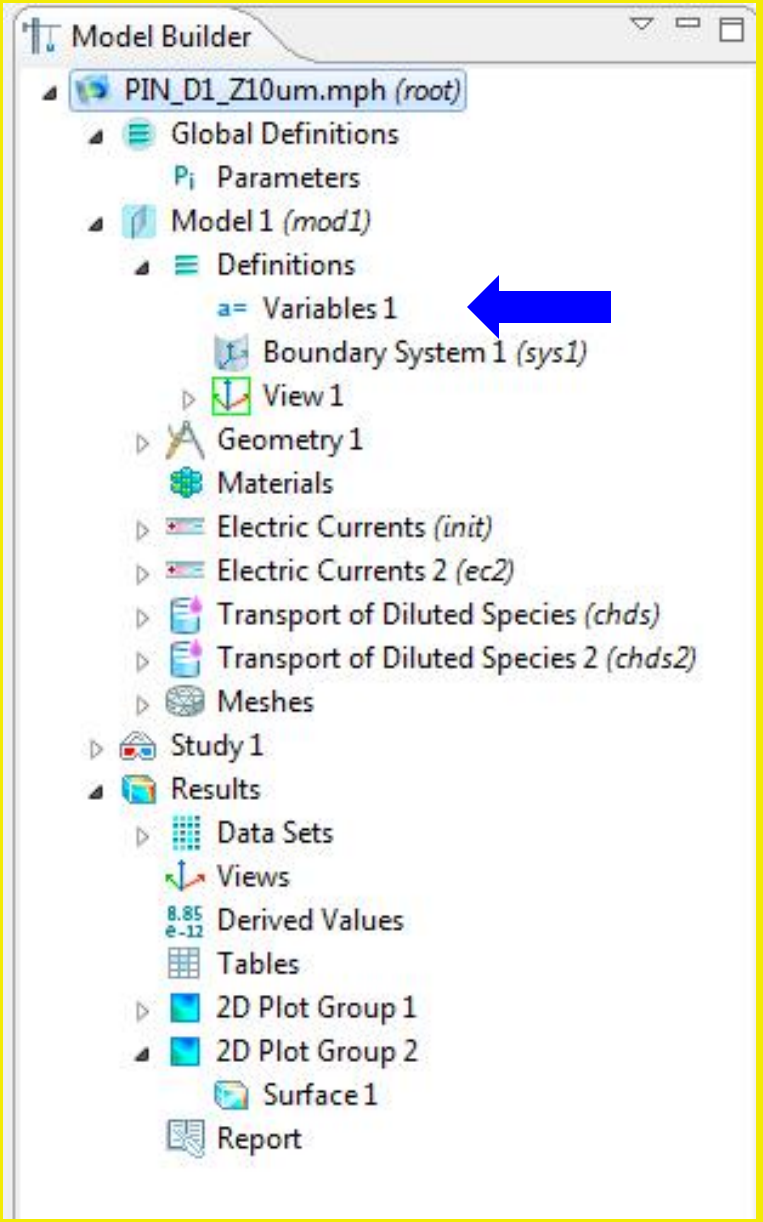

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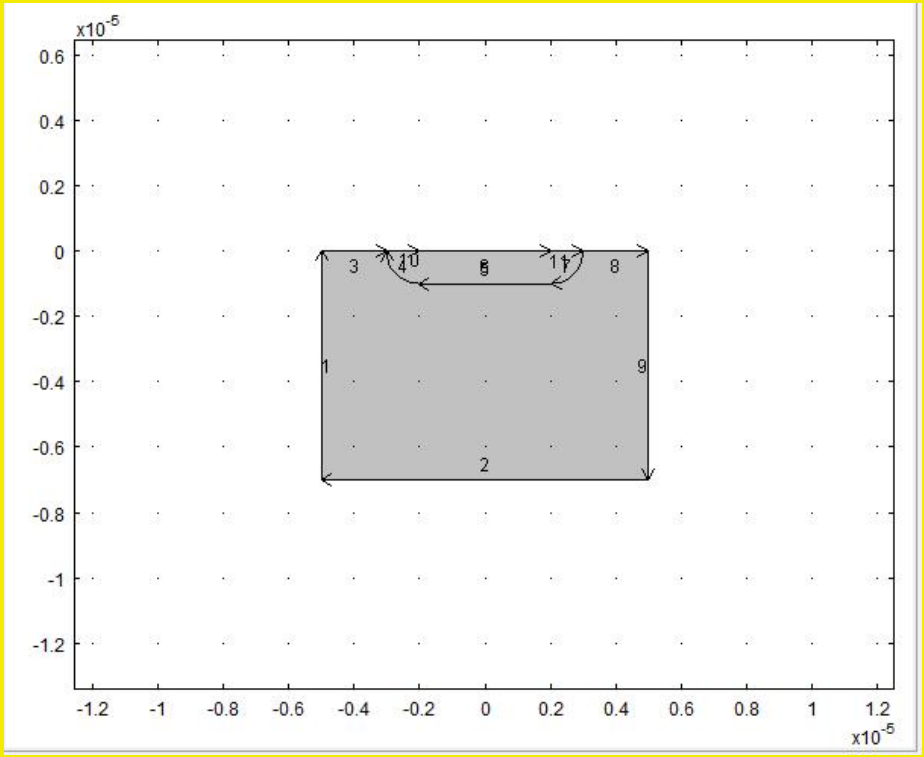
Building the PIN Photodiode Model

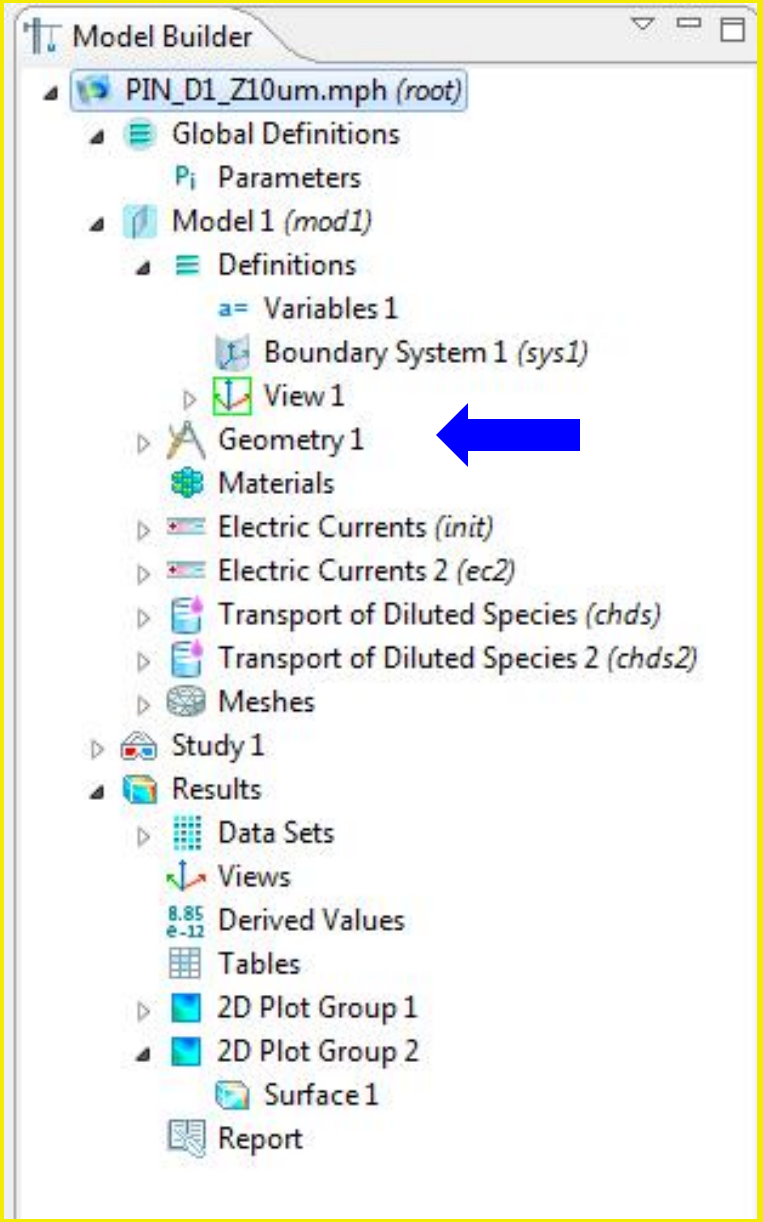
Variables

Variable	Expression	Description
N	NDn+NDnmax*exp(-((y+y1)/ch)^2)-NApmax*exp(-(y/ch)^2)*((abs(x)<ac/2)+(abs(x)>=ac/2)*exp(-((abs(x)-ac/2)/ch)^2))	Doping concentration
n_init	(abs(N)/2+sqrt(N^2/4+ni^2))*(N>=0)+ni^2/(abs(N)/2+sqrt(N^2/4+ni^2))*(N<0)	Charge neutrality electron concentration
p_init	(abs(N)/2+sqrt(N^2/4+ni^2))*(N<0)+ni^2/(abs(N)/2+sqrt(N^2/4+ni^2))*(N>=0)	Charge neutrality hole concentration
V_psi_init	1/c*(-log(p_init/ni)*(N<0)+log(n_init/ni)*(N>=0))	Charge neutrality voltage
RSRH	(cn[1/mol]*cp[1/mol]-ni^2)/(taup*(cn[1/mol]+ni)+taun*(cp[1/mol]+ni))	Recombination term
sigma_si	q*(cn[1/mol]*mun+cp[1/mol]*mup)	Conductivity of doped silicon
cn0	ni*exp(-(V_psi0/Vt))	Thermal Eq electron concentration
cp0	ni*exp(-(V_psi0/Vt))	Thermal Eq hole concentration
sigma_sip	q*cp0*mup	P domain conductivity
sigma_sin	q*cn0*mun	N domain conductivity

Building the PIN Photodiode Model

PIN Photodiode Geometry





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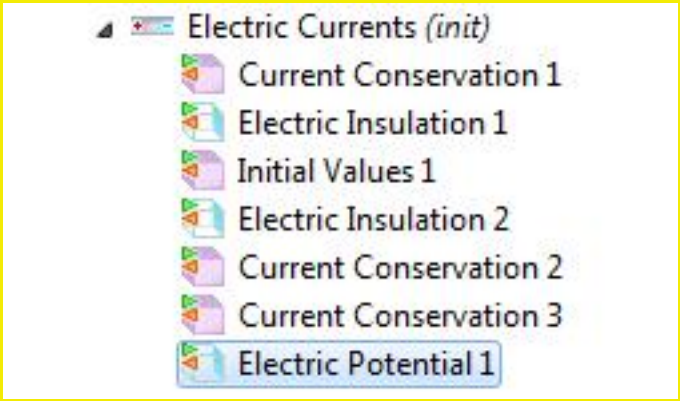
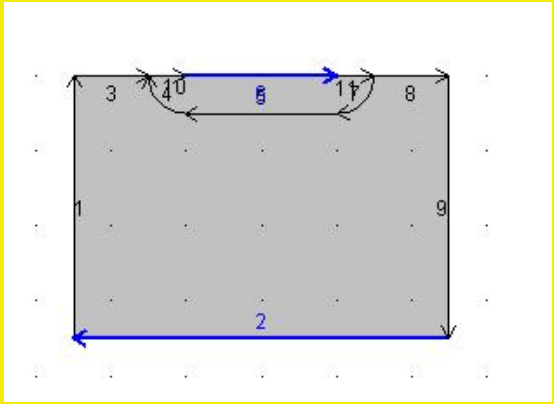
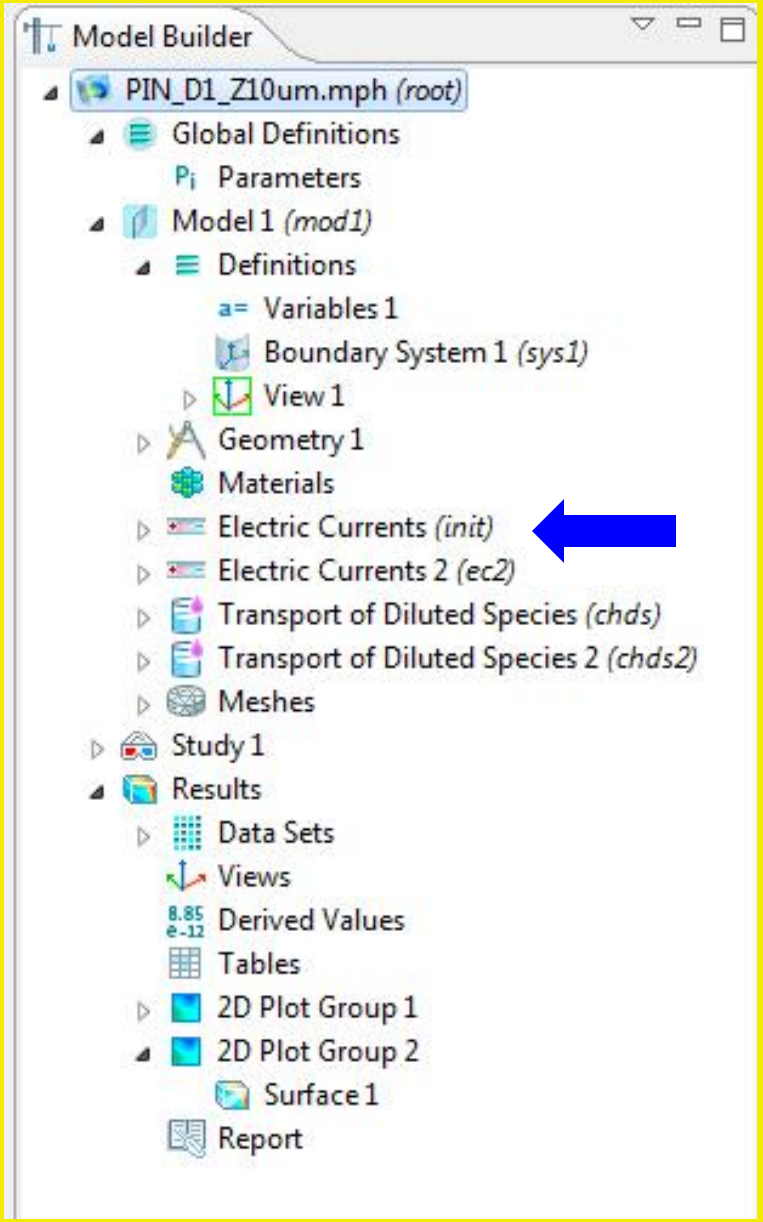
Building the PIN Photodiode Model

PIN Photodiode Initialization







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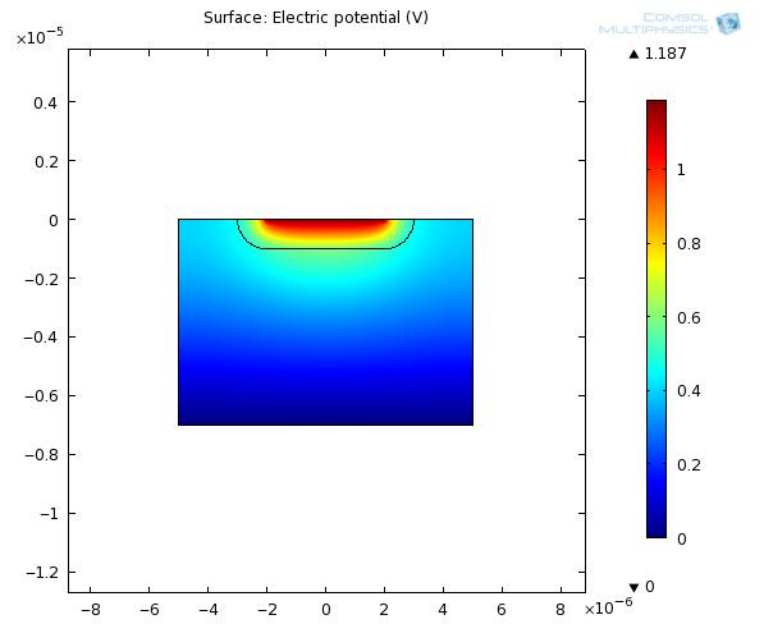
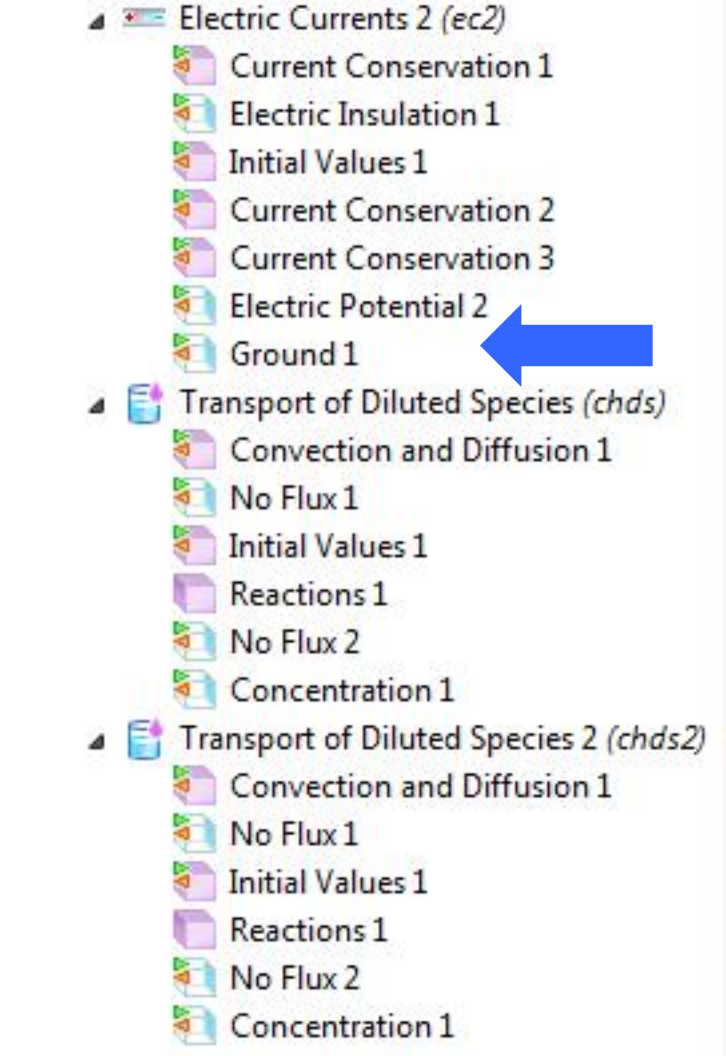
Building the PIN Photodiode Model

PIN Photodiode Calculation





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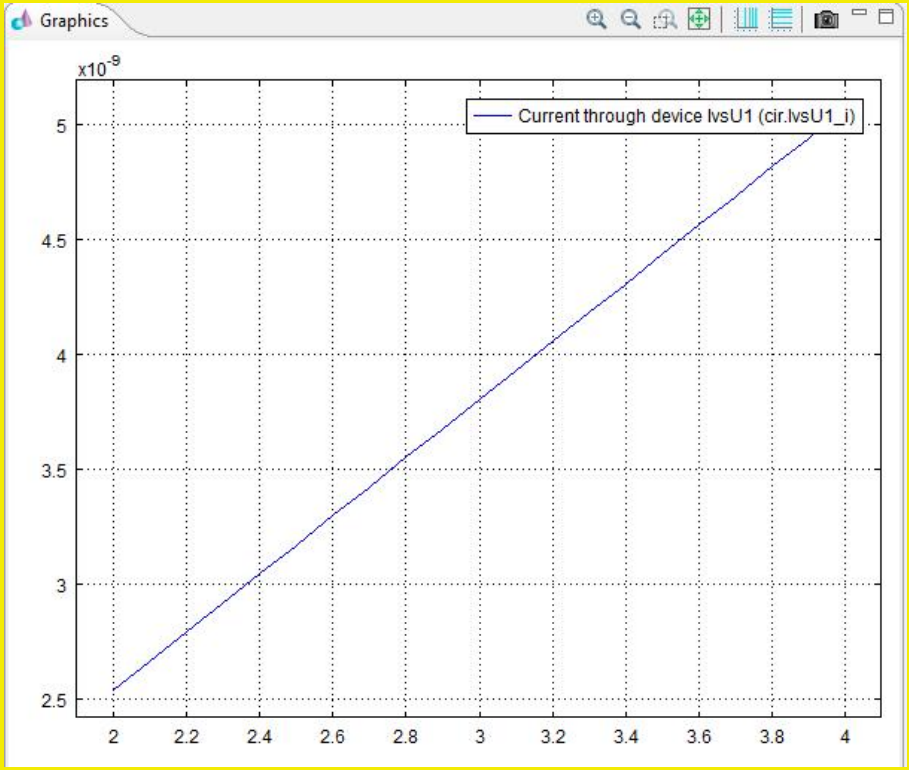
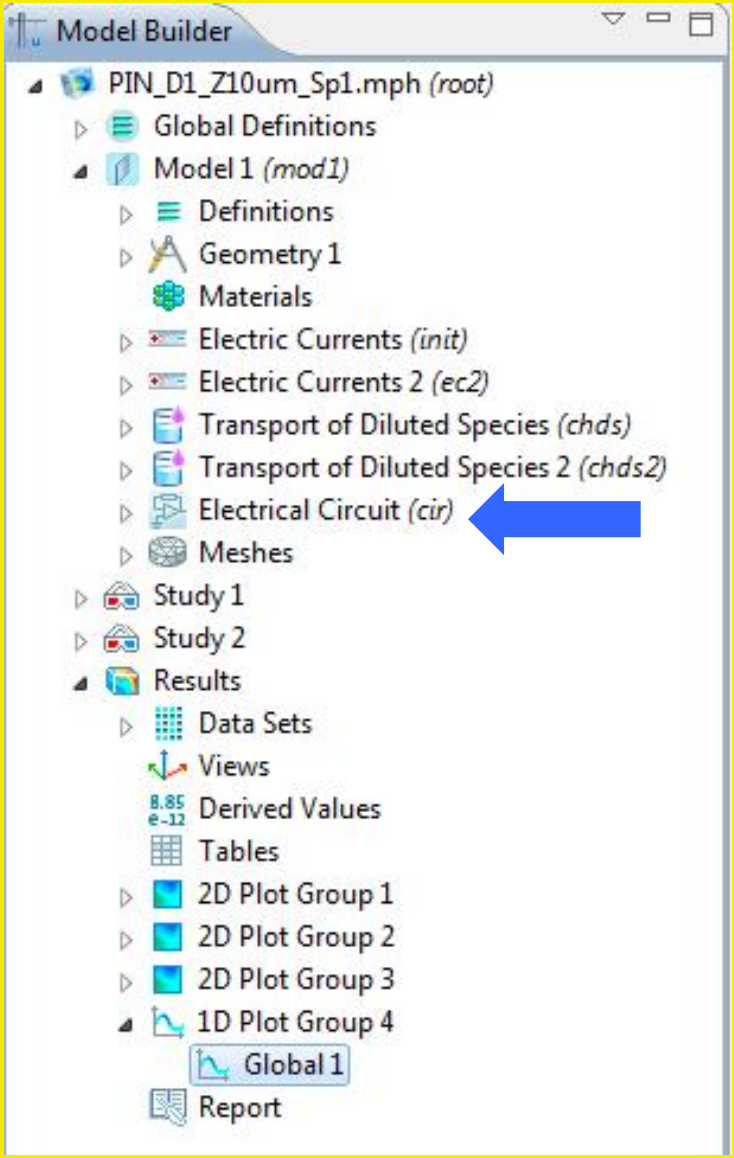
Building the PIN Photodiode Model

PIN Photodiode Calculation & SPICE





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PIN Photodiode Model

Conclusions

1. **AC/DC Conduction Current Semiconductor Models can be built in COMSOL Multiphysics 4.0a, using sufficient care.**
2. **Such Semiconductor Models can be used with SPICE, with proper boundary conditions.**

Thank You!