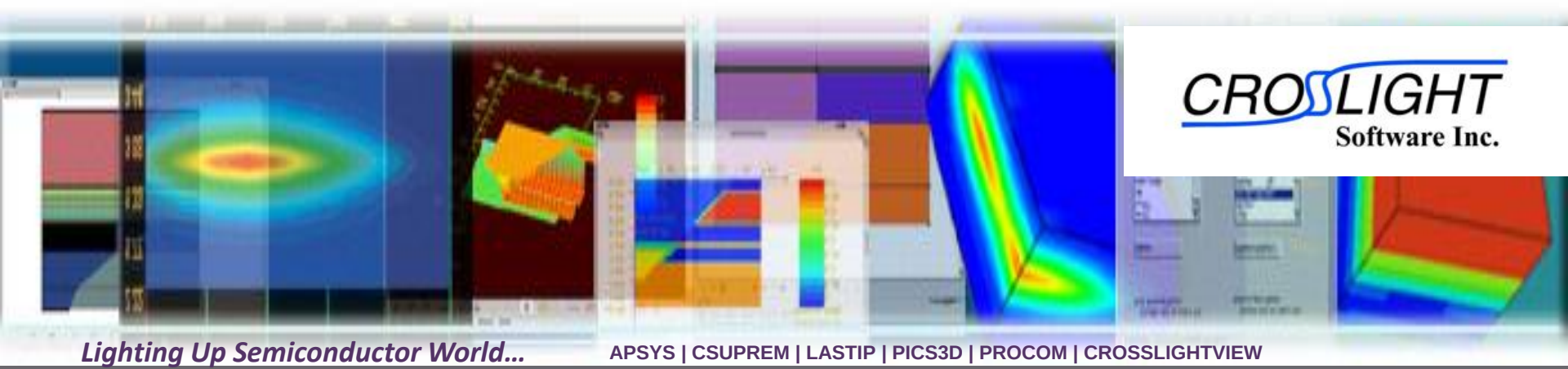
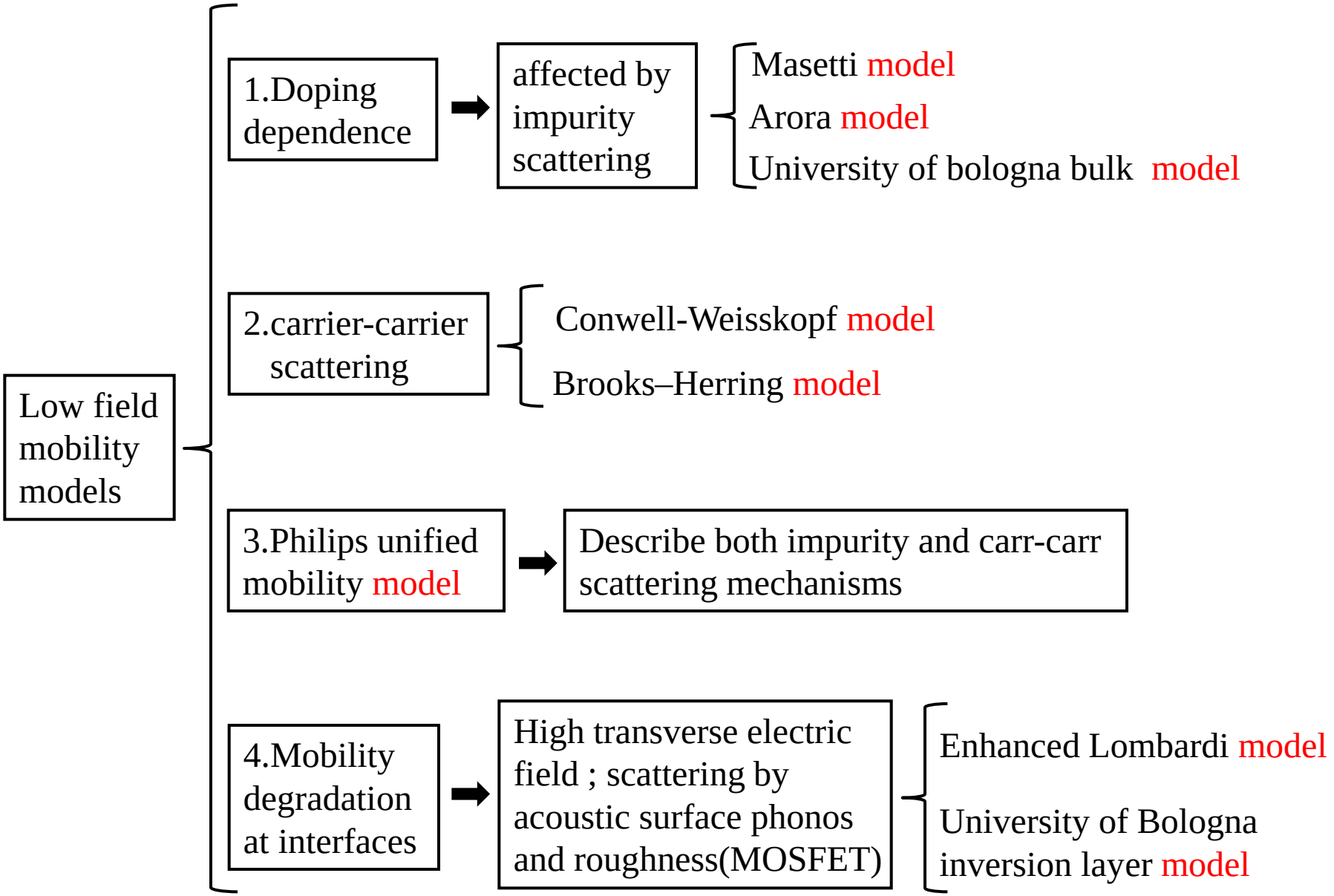


CROSSLIGHT Software Inc.

Low Field Mobility Model

- Overview
- Syntax
- Functions and parameters
- NMOS example



2. Syntax

The statement **low_field_mobility_model** is used to active different mobility models under a low electric field.

- If more than one mobility model is activated, the different mobility contributions are combined in the form:

$$\frac{1}{\mu} = \frac{1}{\mu_{dop}} + \frac{1}{\mu_{eh}} + \frac{1}{\mu_s}$$

where μ_{dop} is the contribution of bulk scattering, μ_{eh} is the contribution of carrier to carrier scattering, and μ_s is the surface contribution.

- The Philips unified mobility model describes mobility degradation due to both bulk scattering and carrier to carrier scattering mechanisms. Therefore, if *el_philips_unified_model /hole_philips_unified_model=yes* is combined with *doping_dependence_model* or *carrier_carrier_model*, APSYS uses only the Philips unified mobility model.

- If *doping_dependence_model=void* and *philips_unified_model=no*, APSYS uses the originally formulas to calculate μ_{dop}:

$$\mu_{oi} = \mu_{1i} + \frac{(\mu_{2i} - \mu_{1i})}{1 + \left(\frac{N_D + N_A + \sum_j N_{tj}}{N_{ri}}\right)^{\alpha_i}} \quad (i = n \text{ or } p)$$

- *channel_interface_dir=horizontal/vetical* is necessary if *degradation_model* is activated.

- *channel_interface_label* is position label specified the location of the interface.

- eg:

  low_field_mobility_model el_philips_unified_model = yes el_phili_umax=0.1417 mater=1

  This statement actives philips unified model for electron, and the parameter umax in the function is specified as 0.1417 $m^2/(V \cdot s)$ for mater number 1.

low_field_mobility_model

Parameter	Data type	Default value
el_doping_dependence_model	char	[void],masetti, arora, uni_bologna
hole_doping_dependence_model	char	[void],masetti, arora, uni_bologna
el_carrier_carrier_model	char	[void],conwell_weisskopf, brooks_herring
hole_carrier_carrier_model	char	[void],conwell_weisskopf, brooks_herring
el_degradation_model	char	[void],enhanced_lombardi, uni_bologna_inversion
hole_degradation_model	char	[void],enhanced_lombardi, uni_bologna_inversion
el_philips_unified_model	char	[no],yes
hole_philips_unified_model	char	[no],yes
channel_interface_dir	char	[void], horizontal, vertical
channel_interface_label	char	[void],mylabel
mater	intg	[1], 2, 3

3.Functions and parameters

Doping dependent mobility model

low_field_mobility_model supports three models for doping-dependent mobility.

Masetti model: $$\mu_{dop} = \mu_{min1} \exp\left(-\frac{P_c}{N_i}\right) + \frac{\mu_{max}\left(\frac{T}{T_0}\right)^{-\zeta} - \mu_{min2}}{1+\left(\frac{N_i}{C_r}\right)^{\alpha}} - \frac{\mu_1}{1+\left(\frac{C_s}{N_i}\right)^{\beta}}$$

Where $N_i = N_A + N_D$ denotes the total concentration of ionized impurities.

Masetti model: Default coefficients

Symbol	Parameter (el_/hole_)	Data type	Elec value	Hole value	Unit
μ_{max}	mase_umax	real	0.1417	0.04705	$m^2/(V \cdot s)$
ζ	mase_exponent	real	2.5	2.2	1
μ_{min1}	mase_umin1	real	0.00522	0.00449	$m^2/(V \cdot s)$
μ_{min2}	mase_umin2	real	0.00522	0	$m^2/(V \cdot s)$
μ_1	mase_u1	real	0.00434	0.0029	$m^2/(V \cdot s)$
P_c	mase_pc	real	0	9.23E+22	m^{-3}
C_r	mase_cr	real	9.68E+22	2.23E+23	m^{-3}
C_s	mase_cs	real	3.34E+26	6.10E+26	m^{-3}
α	mase_alpha	real	0.68	0.719	1
β	mase_beta	real	2.0	2.0	1

Arora model:

$$\mu_{dop} = \mu_{min} + \frac{\mu_d}{1+(\frac{N_i}{N_0})^{A^*}}$$

with

$$\begin{cases} \mu_{min} = A_{min} \cdot (\frac{T}{T_0})^{\alpha_m} \\ \mu_d = A_d \cdot (\frac{T}{T_0})^{\alpha_d} \\ N_0 = A_N \cdot (\frac{T}{T_0})^{\alpha_N} \\ A^* = A_a \cdot (\frac{T}{T_0})^{\alpha_a} \end{cases}$$

where $N_i = N_A + N_D$ denotes the total concentration If ionized impurities, $T_0 = 300K$, and T is the lattice temperature.

Arora model: Default coefficients for silicon

Symbol	Parameter (el_/hole_)	Data type	Elec value	Hole value	Unit
A_{min}	ar_umin	real	0.0088	0.00543	$m^2/(V \cdot s)$
α_m	ar_alpha_m	real	-0.57	-0.57	1
A_d	ar_d	real	0.1252	0.0407	$m^2/(V \cdot s)$
α_d	ar_alpha_d	real	-2.33	-2.23	1
A_N	ar_n	real	1.25E+33	2.35E+23	m^3
α_N	ar_alpha_n	real	2.4	2.4	1
A_a	ar_a	real	0.88	0.88	1
α_a	ar_alpha_a	real	-0.146	-0.146	1

University of Bologna bulk mobility model:

$$\mu_{dop}(N_A, N_D, T) = \mu_0(N_A, N_D, T) + \frac{\mu_L(T) - \mu_0(N_A, N_D, T)}{1 + \left(\frac{N_D}{C_{r1} T_n^{\gamma_{r1}}}\right)^{\alpha} + \left(\frac{N_A}{C_{r2} T_n^{\gamma_{r2}}}\right)^{\beta}} - \frac{\mu_1(N_A, N_D, T)}{1 + \left(\frac{N_D}{C_{s1} T_n^{\gamma_{s1}}} + \frac{N_A}{C_{s2}}\right)^{-2}}$$

with

$$\mu_L(T) = \mu_{max} T_n^{-\gamma + cT_n}$$

$$\mu_0(N_A, N_D, T) = \frac{\mu_{0d} T_n^{-\gamma_{0d}} N_D + \mu_{0a} T_n^{-\gamma_{0a}} N_A}{N_D + N_A}$$

$$\mu_1(N_A, N_D, T) = \frac{\mu_{1d} T_n^{-\gamma_{1d}} N_D + \mu_{1a} T_n^{-\gamma_{1a}} N_A}{N_D + N_A}$$

$$T_n = \frac{T}{300K}$$

Parameters of University of Bologna bulk mobility model

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
μ_{max}	uni_bolo_umax	real	0.1441	0.04705	$m^2/(V \cdot s)$
c	uni_bolo_c	real	0.07	0	1
γ	uni_bolo_gama	real	2.45	2.16	1
γ_{0d}	uni_bolo_gama_0d	real	0.6	1.3	1
μ_{od}	uni_bolo_u_0d	real	0.0055	0.009	$m^2/(V \cdot s)$
γ_{0a}	uni_bolo_gama_0a	real	1.3	0.7	1
μ_{oa}	uni_bolo_u_0a	real	0.0132	0.0044	$m^2/(V \cdot s)$
γ_{1d}	uni_bolo_gama_1d	real	0.5	2.0	1
μ_{1d}	uni_bolo_u_1d	real	0.00424	0.00282	$m^2/(V \cdot s)$
γ_{1a}	uni_bolo_gama_1a	real	1.25	0.8	1
μ_{1a}	uni_bolo_u_1a	real	0.00735	0.00282	$m^2/(V \cdot s)$
γ_{r1}	uni_bolo_gama_r1	real	3.65	2.2	1
C_{r1}	uni_bolo_C_r1	real	8.9E+22	1.3E+24	m^{-3}
γ_{r2}	uni_bolo_gama_r2	real	2.65	3.1	1
C_{r2}	uni_bolo_C_r2	real	1.22E+23	2.45E+23	m^{-3}
γ_{s1}	uni_bolo_gama_s1	real	0.0	6.2	1
C_{s1}	uni_bolo_C_s1	real	2.9E+26	1.1E+24	m^{-3}
C_{s2}	uni_bolo_C_s2	real	7.0E+26	6.1E+26	m^{-3}
α	uni_bolo_alpha	real	0.68	0.77	1
β	uni_bolo_beta	real	0.72	0.719	1

Carrier to carrier scattering model

Low_field_mobility_model supports two models for the description of carrier to carrier scattering.

Conwell-Weisskopf model:

$$\mu_{eh} = \frac{D\left(\frac{T}{T_0}\right)^{\frac{3}{2}}}{\sqrt{np}}\left[\ln\ (1 + F(T/T_0)^2 (pn)^{-1/3})\right]^{-1}$$

Where n/p are the electron and hole densities respectively, T denotes the lattice temperature, and T_0=300K.

Conwell–Weisskopf model: Default parameters

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
D	con_wei_D	real	1.04E+16	1.04E+16	$1/(m \cdot Vs)$
F	con_wei_F	real	7.452E+17	7.452E+17	m^{-2}

Brooks-Herring model:

$$\mu_{eh} = \frac{c_1 \left(\frac{T}{T_0}\right)^{3/2}}{\sqrt{np}} \frac{1}{\phi(\eta_0)}$$

With $$\phi(\eta_0) = \ln(1+\eta_0) - \frac{\eta_0}{1+\eta_0}$$

$$\eta_0(T) = \frac{c_2}{N_c F_{-\frac{1}{2}}\left(\frac{n}{N_c}\right) + N_v F_{-\frac{1}{2}}\left(\frac{p}{N_v}\right)} \left(\frac{T}{T_0}\right)^2$$

Where T denotes the lattice temperature, $T_0 = 300K$.n and p are the electron and hole densities, respectively, and $F_{-\frac{1}{2}}\left(\frac{n}{N_c}\right)$ is the derivative of the Fermi integral.

Brooks-Herring model: Default parameters

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
c_1	bro_her_c1	real	1.56E+15	1.56E+15	$1/(m \cdot Vs)$
c_2	bro_her_c2	real	7.63E+25	7.63E+25	m^{-3}

Philips unified mobility model:

$$\frac{1}{\mu_{i,b}} = \frac{1}{\mu_{i,L}} + \frac{1}{\mu_{i,DAeh}}$$

$\mu_{i,L}$ represents phonon scattering, $\mu_{i,DAeh}$ accounts for all other bulk scattering mechanisms (due to free carriers, and ionized donors and acceptors). The index "i" takes the value "e" for electrons and "h" for holes.

$$\mu_{i,L} = \mu_{i,max}(\frac{T}{T_0})^{-\theta_i}$$

where T denotes the lattice temperature and $T_0 = 300K$.

$$\mu_{i,DAeh} = \mu_{i,N}\left(\frac{N_{i,sc}}{N_{i,sc,eff}}\right)\left(\frac{N_{i,ref}}{N_{i,sc}}\right)^{\alpha_i} + \mu_{i,c}(\frac{n+p}{N_{i,sc,eff}})$$

with

$$\mu_{i,N} = \frac{{\mu_{i,max}}^2}{\mu_{i,max}-\mu_{i,min}}\left(\frac{T}{T_0}\right)^{3\alpha_i-1.5}$$

$$\mu_{i,c} = \frac{\mu_{i,max}\mu_{i,min}}{\mu_{i,max}-\mu_{i,min}}\left(\frac{T}{T_0}\right)^{0.5}$$

for the electrons:

$$N_{i,sc} = N_{e,sc} = N_D^* + N_A^* + p$$

$$N_{i,sc,eff} = N_{e,sc,eff} = N_D^* + G(P_e)N_A^* + \frac{p}{F(P_e)}$$

and for the holes:

$$N_{i,sc} = N_{h,sc} = N_A^* + N_D^* + n$$

$$N_{i,sc,eff} = N_{h,sc,eff} = N_A^* + G(P_h)N_D^* + \frac{n}{F(P_h)}$$

The effects of clustering of donors (N_D^*) and acceptors (N_A^*) at ultrahigh concentrations are described as:

$$N_D^* = N_D\left[1 + \frac{1}{c_D + \left(\frac{N_{D,ref}}{N_D}\right)^2}\right]$$

$$N_A^* = N_A\left[1 + \frac{1}{c_A + \left(\frac{N_{A,ref}}{N_A}\right)^2}\right]$$

The analytic functions are given by:

$$F(P_i) = \frac{0.7643P_i^{0.6478} + 2.2999 + 6.5505(\frac{m_i^*}{m_j^*})}{P_i^{0.6478} + 2.3670 - 0.8552(\frac{m_i^*}{m_j^*})}$$

$$G(P_i) = 1 - \frac{a_g}{\left[b_g + P_i\left(\frac{m_0}{m_i^*}\frac{T}{T_0}\right)^{\alpha_g}\right]^{\beta_g}} + \frac{c_g}{\left[P_i\left(\frac{m_0}{m_i^*}\frac{T}{T_0}\right)^{\alpha_g'}\right]^{\gamma_g}}$$

where m_0 is the free carrier mass and m_i^* denotes a fit parameter (which is related to effective carrier mass). m_j^* denotes the corresponding fit parameter for holes if i=e and for electrons if i=h.

The screening parameter P_i is given by a weighted harmonic mean of the Brooks-Herring approach and Conwell-Weisskopf approach:

$$P_i = \left[\frac{f_{CW}}{3.97 \times 10^{13} N_{i,sc}^{-2/3}} + \frac{f_{BH}}{\frac{1.36 \times 10^{26}}{n+p}(\frac{m_i^*}{m_0})}\right]^{-1}\left(\frac{T}{T_0}\right)^2$$

Philips unified mobility model parameters (silicon)

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
$\mu_{i,max}$	phili_umax	real	0.1417	0.04705	$m^2/(V \cdot s)$
$\mu_{i,min}$	phili_umin	real	0.00522	0.00449	$m^2/(V \cdot s)$
θ	phili_theta	real	2.285	2.247	1
$N_{e/h,ref}$	phili_e_ref	real	9.68E+22	2.23E+23	m^{-3}
α	phili_alpha	real	0.68	0.719	1
$N_{D,ref}$	phili_d_ref	real	4.0E+26	4.0E+26	m^{-3}
$N_{\mathrm{A},ref}$	phili_a_ref	real	7.2E+26	7.2E+26	m^{-3}
c_D	phili_c_d	real	0.21	0.21	1
c_A	phili_c_a	real	0.5	0.5	1
m_e^*	phili_me	real	1.0	1.0	1
m_h^*	phili_mh	real	1.258	1.258	1
m_0	phili_m0	real	1.0	1.0	1
f_{CW}	phili_fcw	real	2.459	2.459	1
f_{BH}	phili_fbh	real	3.828	3.828	1
a_g	phili_a_g	real	0.89233	0.89233	1
b_g	phili_b_g	real	0.41372	0.41372	1
c_g	phili_c_g	real	0.005978	0.005978	1
α_g	phili_alpha_g	real	0.28227	0.28227	1
α_g'	phili_alpha_g2	real	0.72169	0.72169	1
β_g	phili_beta_g	real	0.19778	0.19778	1
γ_g	phili_gama_g	real	1.80618	1.80618	1

Mobility degradation at interfaces:

In the channel region of a MOSFET, the high transverse electric field forces carriers to interact strongly with the semiconductor-insulator interface. Carriers are subjected to scattering by acoustic surface phonons and surface roughness . The models in this section describe mobility degradation caused by these effects.

University of Bologna inversion layer mobility model:

$$\frac{1}{\mu} = \frac{1}{\mu_{bsc}} + \frac{D}{\mu_{ac}} + \frac{D}{\mu_{sr}}$$

where $\frac{1}{\mu_{bsc}}$ is the contribution of Coulombic scattering, and $\frac{1}{\mu_{ac}}\frac{1}{\mu_{sr}}$ are those of surface phonons and surface roughness scattering, respectively.

$\mathrm{D} = \mathrm{e}^{-\mathrm{x}/l_{crit}}$ (where x is the distance from the interface and $l_{crit}\ a\ fit\ parameter$) is a damping that switches off the inversion layer terms far away from the interface.

$$\mu_{bsc} = \mu_b[D(1 + f_{sc}^{\tau})^{\frac{1}{\tau}} + (1 - D)]$$

Where μ_b is given by the bulk mobility model.
The screening function is given by:

$$f_{sc} = (\frac{N_1}{N_A + N_D})^{\eta}\frac{N_{min}}{N_A + N_D}$$

N_{min} is the minority carrier concentration.
The main scattering mechanisms (surface phonons and surface roughness scattering) are expressed by:

$$\mu_{ac} = c\left(\frac{T}{T_0}\right)^{-\gamma_c}(\frac{N_A + N_D}{N_2})^{a}\frac{1}{F_{\perp}{}^{\delta}}$$

$$\mu_{sr} = \mathrm{d}\left(\frac{T}{T_0}\right)^{\gamma_d}(\frac{N_A + N_D + N_3}{N_4})^{b}\frac{1}{F_{\perp}{}^{\lambda}}$$

$F_{\perp}$ is the electric field normal to semiconductor-insulator interface.

Parameters of University of Bologna inversion layer mobility model

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
N_1	uni_boloinve_n1	real	2.34E+22	2.02E+22	m^{-3}
N_2	uni_boloinve_n2	real	4.00E+21	7.80E+21	m^{-3}
N_3	uni_boloinve_n3	real	1.00E+23	2.00E+21	m^{-3}
N_4	uni_boloinve_n4	real	2.40E+24	6.60E+23	m^{-3}
d	uni_boloinve_d	real	5.80E+15	7.82E+11	$m^2/(V \cdot s)$
γ_d	uni_boloinve_gamad	real	0	1.4	1
c	uni_boloinve_c	real	1.86	0.5726	$m^2/(V \cdot s)$
γ_c	uni_boloinve_gamac	real	1.6	1.3	1
τ	uni_boloinve_tau	real	1.0	3.0	1
η	uni_boloinve_eta	real	0.3	0.5	1
a	uni_boloinve_a	real	0.026	-0.02	1
b	uni_boloinve_b	real	0.11	0.08	1
l_{crit}	uni_boloinve_lcrit	real	1.0E-8	1.0E-8	m
δ	uni_boloinve_delta	real	0.29	0.3	1
λ	uni_boloinve_lambda	real	2.64	2.24	1

Enhanced Lombardi model:

$$\frac{1}{\mu} = \frac{1}{\mu_b} + \frac{D}{\mu_{ac}} + \frac{D}{\mu_{sr}}$$

μ_b is given by the bulk mobility model.
The surface contribution due to acoustic phonon scattering has the form:

$$\mu_{ac} = \frac{B}{F_\perp} + \frac{C(N_i/N_0)^\lambda}{F_\perp{}^{\frac{1}{3}}(T/T_0)^k}$$

$$\mu_{sr} = \left(\frac{\left(F_\perp/F_{ref}\right)^{A^*}}{\delta} + \frac{F_\perp{}^3}{\eta} \right)^{-1}$$

where $N_i = N_A + N_D$, $T_0 = 300K$. The reference field $F_{ref} = 1V/cm$. $\mathrm{D} = \mathrm{e}^{-\mathrm{x}/l_{crit}}$ (where x is the distance from the interface and l_{crit} $a\ fit\ parameter$) is a damping that switches off the inversion layer terms far away from the interface. $F_\perp$ is the transverse electric field normal to the semiconductor-insulator interface. And the exponent A^* is described as:

$$A^* = \mathrm{A} + \frac{\alpha_\perp (n+p) N_{ref}{}^\nu}{(N_i + N_1)^\nu}$$

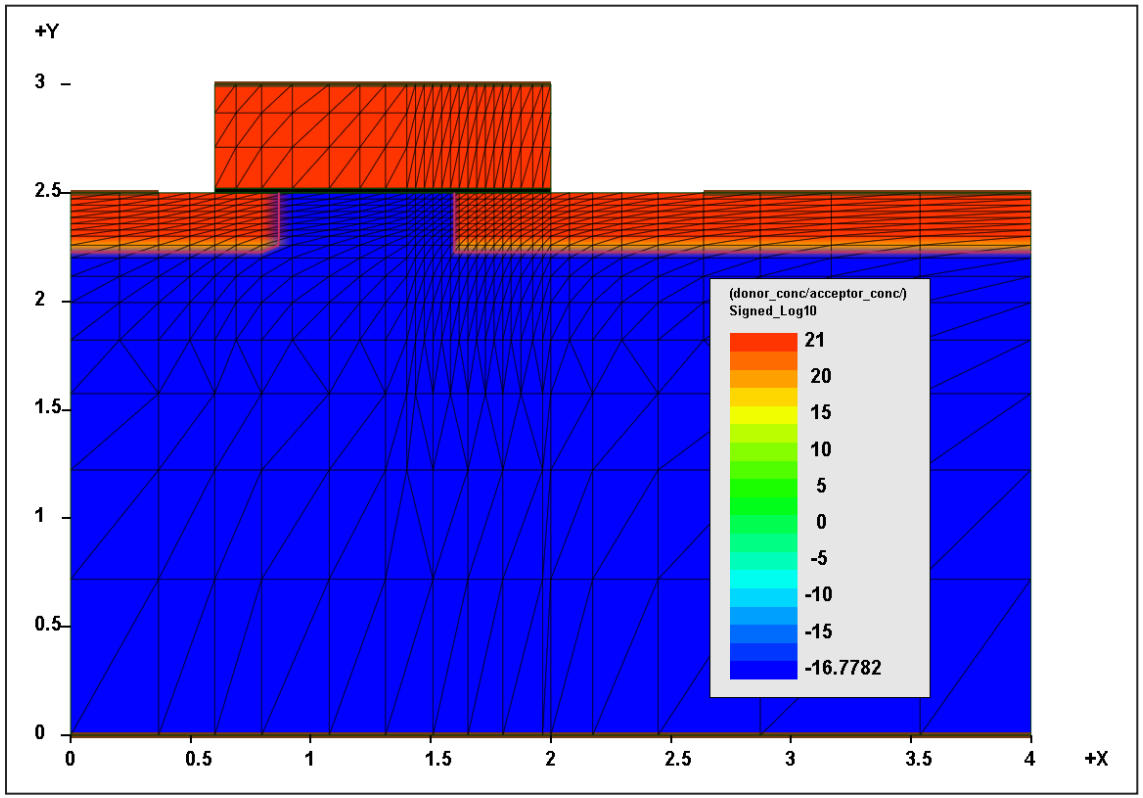
where the reference doping concentration $N_{ref} = 1cm^{-3}$.

Lombardi model: Default coefficients for silicon

Symbol	Parameter(el_/hole_)	Data type	Elec value	Hole value	Unit
B	lombard_B	real	4.75E+5	9.925E+4	$\mathrm{m/s}$
C	lombard_C	real	0.26921	1.36788	$m^{5/3}/(V^{2/3}s)$
N_0	lombard_n0	real	1.0E+6	1.0E+6	m^{-3}
λ	lombard_lambda	real	0.1250	0.0317	1
k	lombard_k	real	1.0	1.0	1
δ	lombard_delta	real	5.82E+10	2.0546E+10	$m^2/(V \cdot s)$
A	lombard_A	real	2.0	2.0	1
$\alpha_\perp$	lombard_alpha	real	0	0	m^3
N_1	lombard_n1	real	1.0E+6	1.0E+6	m^{-3}
ν	lombard_v	real	1.0	1.0	1
η	lombard_eta	real	5.82E+32	2.0546E+32	$V^2/(m \cdot s)$
l_{crit}	lombard_lcrit	real	1.0E-8	1.0E-8	m

4.NMOS example

This example is an n-type mosfet.



Layer Structure:

The layer file used to define this device is shown below:

```
$file:nmos.layer
begin_layer
$
rotation angle=0.00
column  column_num=1  w=0.6  mesh_num=5  r=0.8
column  column_num=2  w=0.8  mesh_num=8  r=-1.2
column  column_num=3  w=0.4  mesh_num=12  r=1.
column  column_num=4  w=0.2  mesh_num=6  r=-1.2
column  column_num=5  w=2.  mesh_num=10  r=1.25
$
bottom_contact column_num=1 from=0 to=0.6 contact_num=1 contact_type=ohmic
bottom_contact column_num=2 from=0 to=0.8 contact_num=1 contact_type=ohmic
bottom_contact column_num=3 from=0 to=0.4 contact_num=1 contact_type=ohmic
bottom_contact column_num=4 from=0 to=0.2 contact_num=1 contact_type=ohmic
bottom_contact column_num=5 from=0 to=2. contact_num=1 contact_type=ohmic
$
layer_mater macro_name=si column_num=1 p_doping=6.e+22
layer_mater macro_name=si column_num=2 p_doping=6.e+22
layer_mater macro_name=si column_num=3 p_doping=6.e+22
layer_mater macro_name=si column_num=4 p_doping=6.e+22
layer_mater macro_name=si column_num=5 p_doping=6.e+22
layer  d=2.3  n=10  r=0.7
```

```
layer_mater macro_name=si column_num=1 p_doping=6.e+22
layer_mater macro_name=si column_num=2 p_doping=6.e+22
layer_mater macro_name=si column_num=3 p_doping=6.e+22
layer_mater macro_name=si column_num=4 p_doping=6.e+22
layer_mater macro_name=si column_num=5 p_doping=6.e+22
layer  d=0.2  n=8  r=1.
layer_position  label=mylabel  location=top
$
layer_mater macro_name=void column_num=1
layer_mater macro_name=sio2 insulator_macro=yes
column_num=2
layer_mater macro_name=sio2 insulator_macro=yes
column_num=3
layer_mater macro_name=sio2 insulator_macro=yes
column_num=4
layer_mater macro_name=void column_num=5
layer  d=0.02  n=4  r=1.2
$
layer_mater macro_name=void column_num=1
layer_mater macro_name=poly column_num=2
layer_mater macro_name=poly column_num=3
layer_mater macro_name=poly column_num=4
layer_mater macro_name=void column_num=5
layer d=0.48 n=4 r=1.2 z_gaussian_tail=0.0001
top_contact  column_num=1  from=0  to=0.4  contact_num=4
contact_type=ohmic
top_contact  column_num=2  from=0  to=0.8  contact_num=2
contact_type=ohmic
top_contact  column_num=3  from=0  to=0.4  contact_num=2
contact_type=ohmic
top_contact  column_num=4  from=0  to=0.2  contact_num=2
contact_type=ohmic
top_contact  column_num=5  from=0.6  to=2.  contact_num=3
contact_type=ohmic
end_layer
```

Simulation Setup

To run the simulation, we use the following .sol file. Different mobility models can be choosed using “low_field_mobility_model”:

```
$file:nmos.sol
$**********
begin
convention positive_current_flow=inward

load_mesh mesh_inf=nmos.msh
output sol_outf=nmos.out
include file=nmos.doping
include file=nmos.mater

$ source and drain doping
doping impurity=shal_dopant charge_type=donor max_conc=1.e27  &&
  x_prof=(0.0, 0.90,  0.001, 0.001)  &&
  y_prof= 2.30, 2.50,  0.02, 0.0001)
doping impurity=shal_dopant charge_type=donor max_conc=1.e27  &&
  x_prof=(1.60, 4.0,  0.001, 0.001)  &&
  y_prof= 2.30, 2.50,  0.02, 0.0001)

$ poly doping
doping impurity=shal_dopant charge_type=donor max_conc=1.e27  &&
  x_prof=(0.6, 2.0,  0.001, 0.001 )  &&
  y_prof=(2.52, 3.0,  0.0001, 0.0001)
```

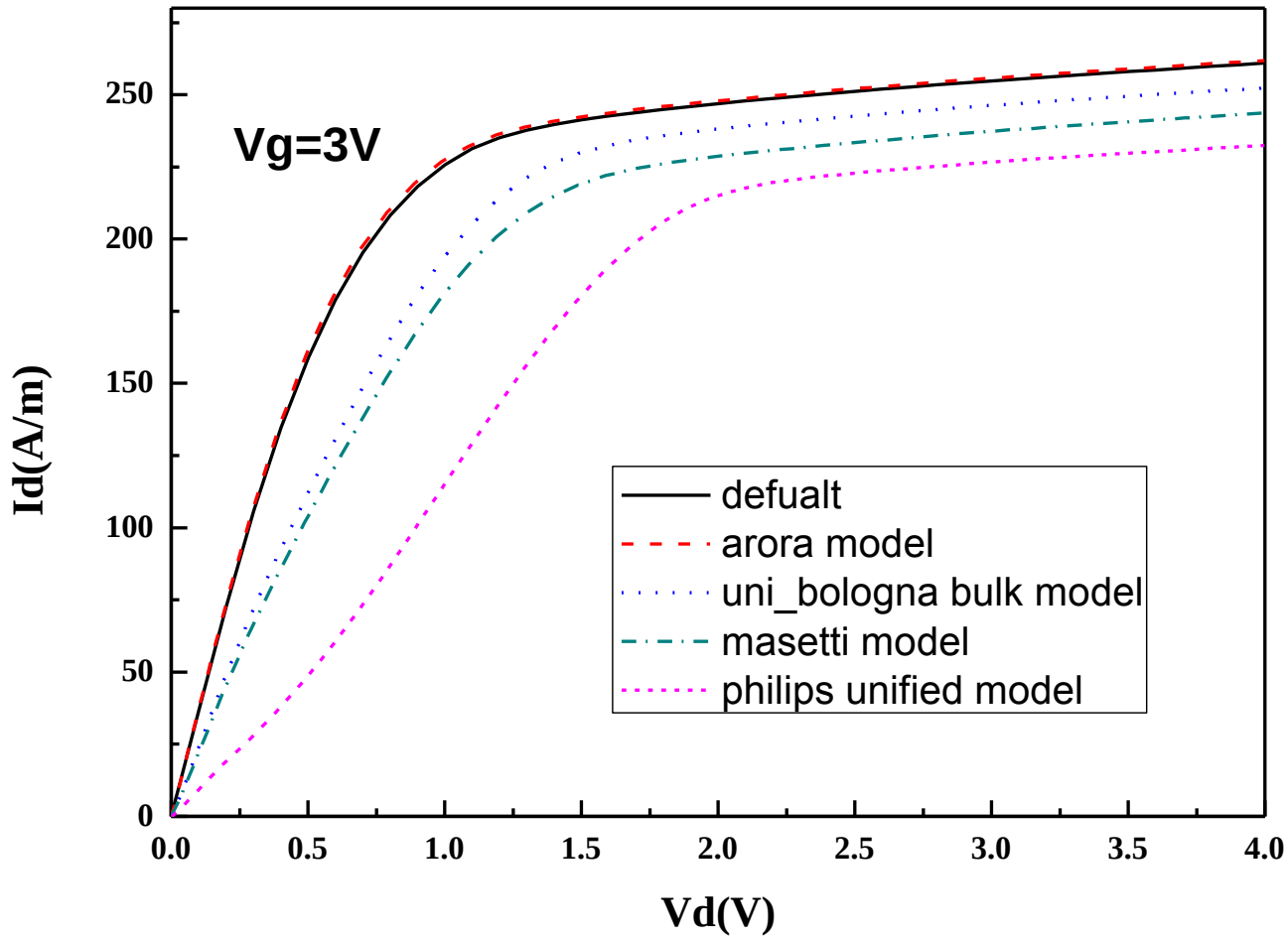
```
$ use low field mobility model
$ use masetti and enhanced lombardi model for both electrons and
holes
low_field_mobility_model mater=1                    &&
  el_philips_unified_model =no                      &&
  el_doping_dependence_model=masetti                &&
  el_carrier_carrier_model=void                     &&
  el_degradation_model=enhanced_lombardi            &&
  hole_philips_unified_model=no                     &&
  hole_doping_dependence_model=masetti              &&
  hole_carrier_carrier_model=void                   &&
  hole_degradation_model=enhanced_lombardi          &&
  channel_interface_dir=horizontal  channel_interface_label=mylabel

$ *************** IdVd ****************
newton_par damping_step=8. max_iter=100 print_flag=3
equilibrium
newton_par damping_step=5. max_iter=60 print_flag=3
scan var=voltage_2 value_to=3. init_step=0.001 &&
    max_step=0.2 min_step=1.e-4
scan var=voltage_ value_to=4. init_step=0.001 &&
    max_step=0.2 min_step=1.e-6

$ *************** IdVg *****************
newton_par damping_step=8. max_iter=60 print_flag=3
equilibrium
newton_par damping_step=4. max_iter=60 print_flag=3
scan var=voltage_3 value_to=3. init_step=0.001 &&
    max_step=0.2 min_step=1.e-4
scan var=voltage_2 value_to=5. init_step=0.001 &&
    max_step=0.2 min_step=1.e-6

end
```

Post-Processing

After the simulation, we can plot the results with the following .plt file.

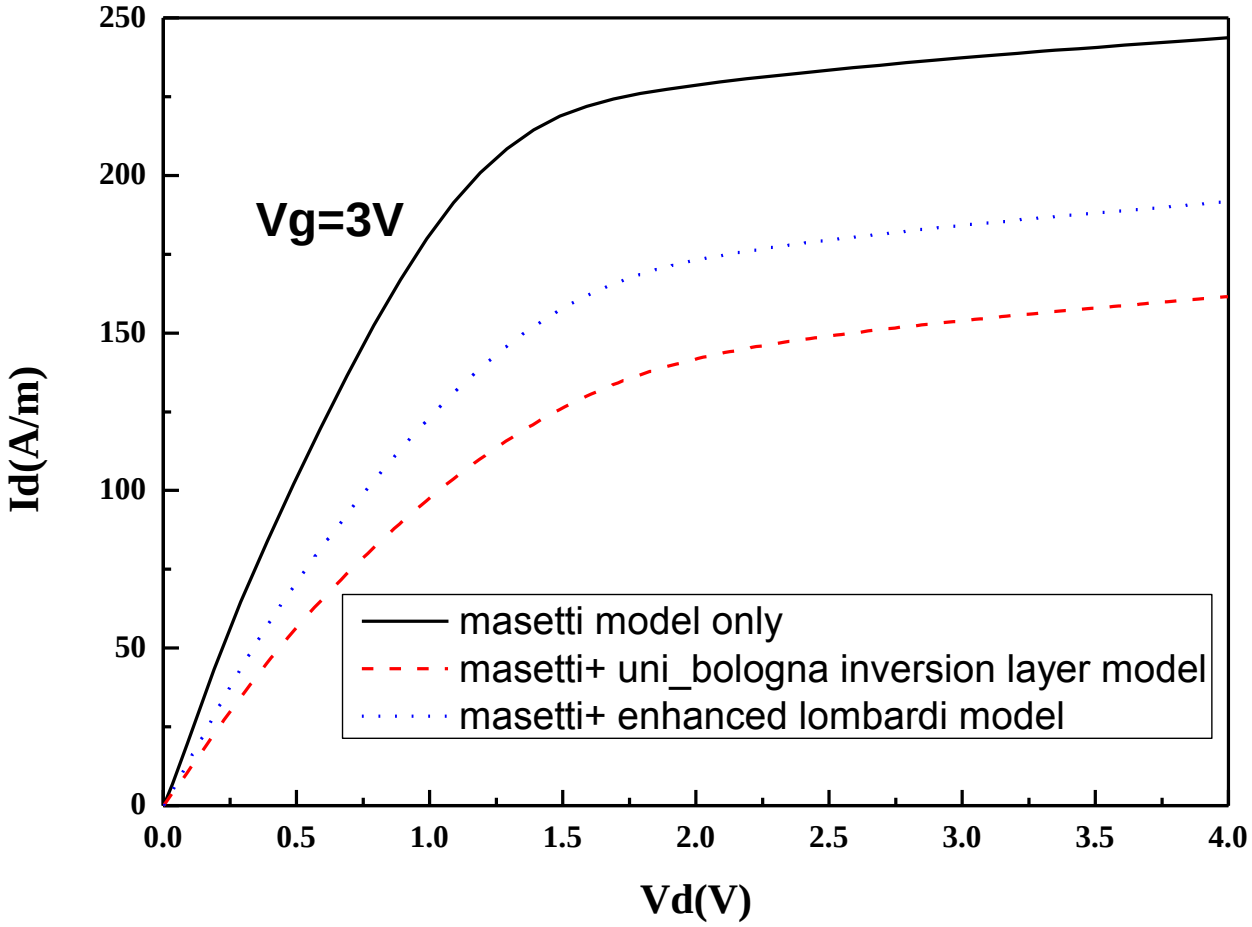
```
$file:nmos.plt
$ **************
begin_pstprc
plot_data plot_device=postscript

define_alias name=current_3 alias=%Id
define_alias name=voltage_3 alias=%Vd
define_alias name=voltage_2 alias=%Vg
$plot IdVd-curve
get_data  main_input=nmos.sol sol_inf=nmos.out &&
  xy_data=(3 3) scan_data=(1 3)
plot_scan scan_var=%Vd variable=%Id
$plot IdVg-curve
get_data  main_input=nmos.sol sol_inf=nmos.out &&
  xy_data=(6 6) scan_data=(4 6)
plot_scan scan_var=%Vg variable=%Id  data_file=idvg.dat

end_pstprc
```

IdVd



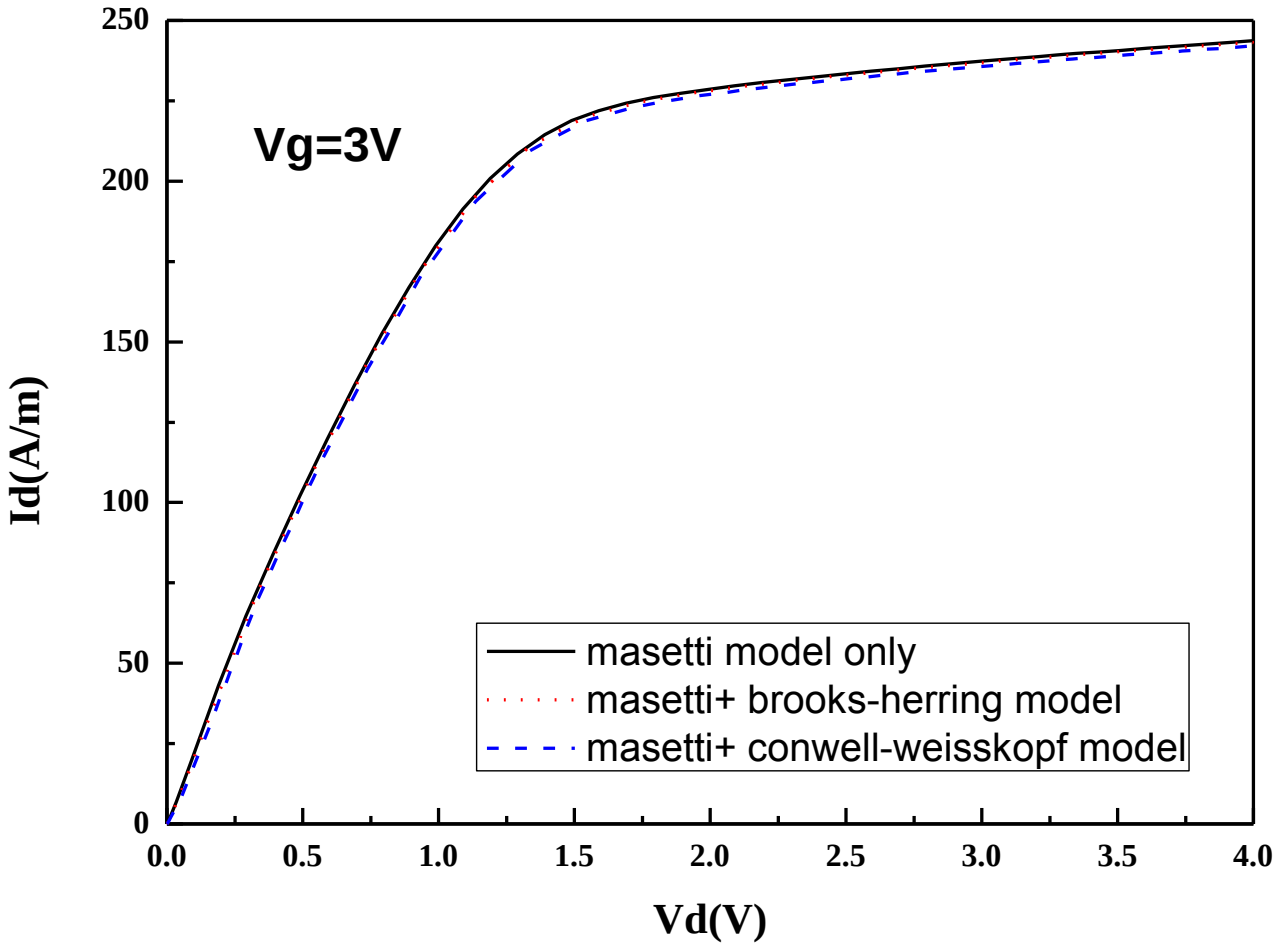
IdVd curve using different mobility models

IdVd



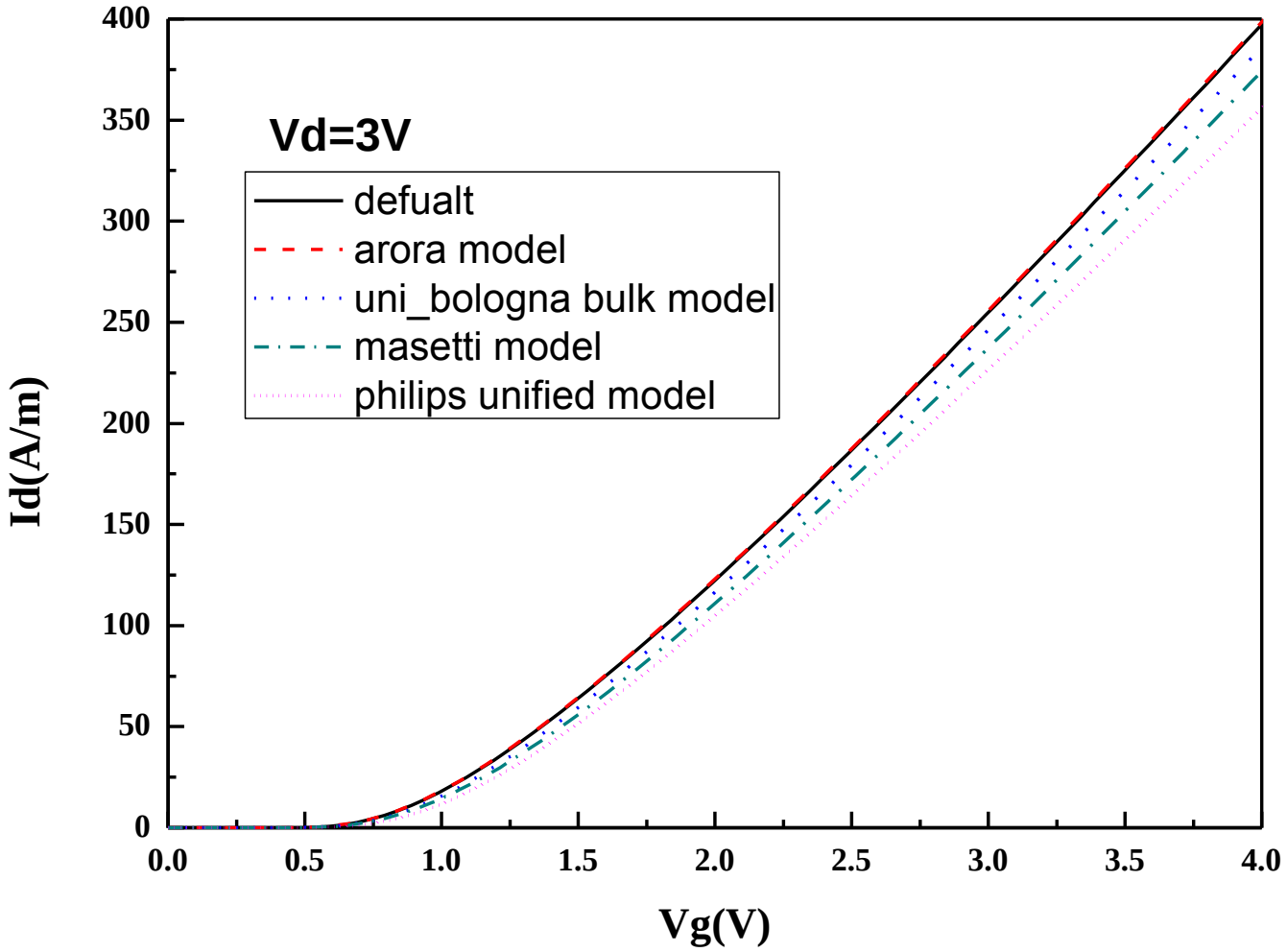
Masetti model combined with different interface models

IdVd



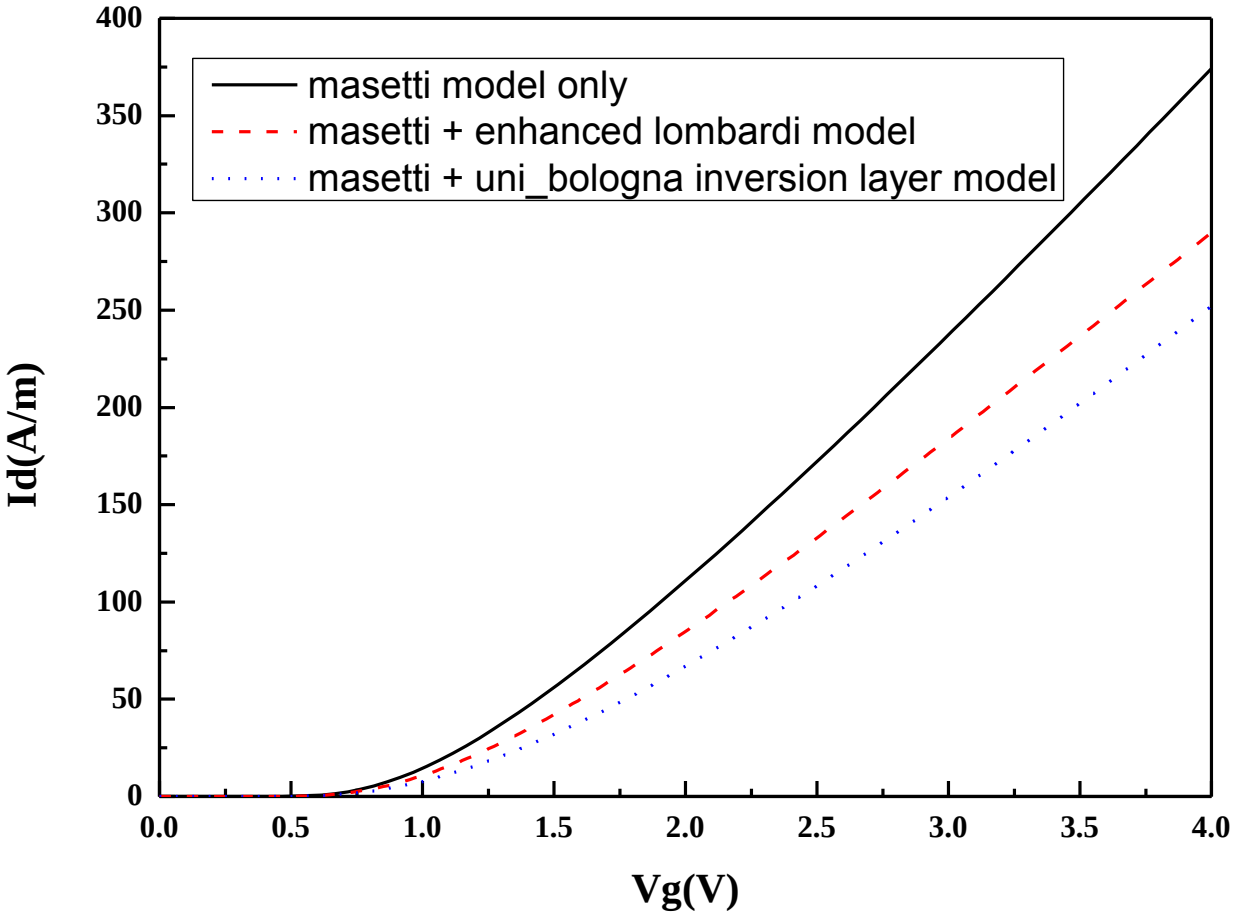
Masetti model combined with different carrier-carrier scattering models

IdVg



IdVg curve using different mobility models

IdVg



Masetti model combined with different interface models

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