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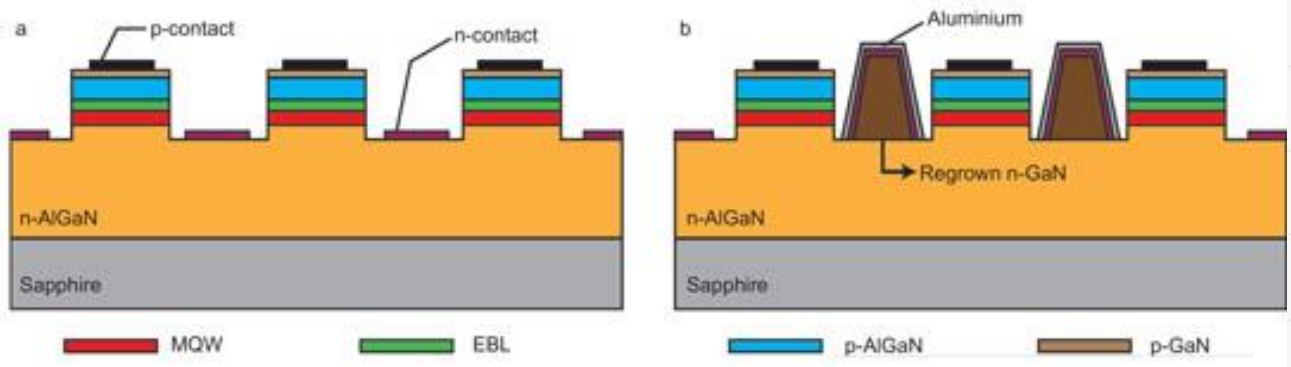
Elementy i układy optoelektroniczne



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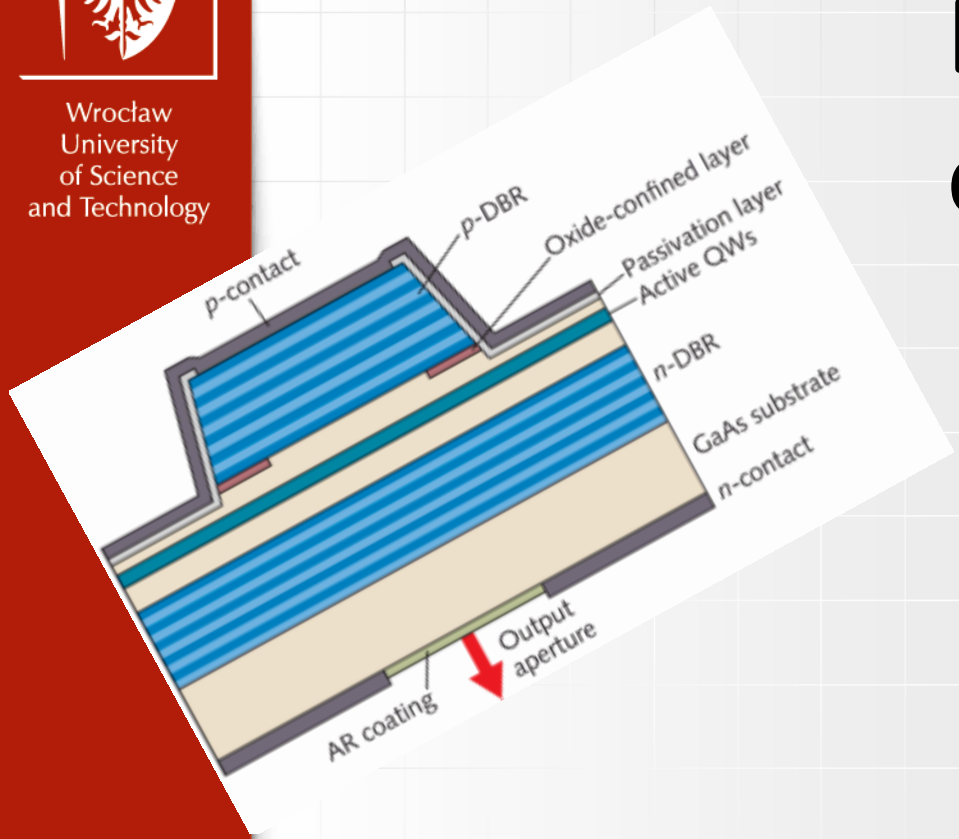
Elementy i układy optoelektroniczne



Wstęp II

CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Dr inż. Damian Radziewicz

Wrocław 2019

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Wprowadzenie

- Struktura LED
- Plik typu **.sol**
- Struktura detektora MSM
- Pliki typu **.layer** i **.sol**

Simulation software by:

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Przykład struktury modelowanej

1 μm - $Al_{0.5}Ga_{0.5}As$ - $p=1.0\times10^{24}\ m^{-3}$
0.2 μm - GaAs - undoped; region aktywny
1 μm - $Al_{0.5}Ga_{0.5}As$ - $n=1.0\times10^{24}\ m^{-3}$

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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

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Plik typu .sol

Definicja struktury przyrządu LED – test1.sol

```
$file:test1.sol
begin
  load_mesh mesh_inf=test1.msh
  include file=test1.mater
  include file=test1.doping
  output sol_outf=test1.out
  newton_par damping_step=5. max_iter=100 print_flag=3
  use_sor max_iter=3000 print_sor=noprint
  init_wave &&
    length= 0.2000E+03 backg_loss=500. &&
    boundary_type=[2 2 1 1] init_wavel= 0.8300E+00 mirror_ref=0.32 &&
    wavel_range=[ 0.8100E+00 0.8500E+00]
  equilibrium
  newton_par damping_step=1. print_flag=3
  scan var=voltage_1 value_to= -0.1345E+01 print_step= 0.1345E+01 &&
    init_step= 0.2689E+00 min_step=1.e-5 max_step=0.5
  scan var=current_1 value_to= 0.2500E+03 print_step= 0.2500E+03 &&
    init_step= 0.2500E+01 min_step=1.e-5 max_step= 0.2500E+02
end
```

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Plik typu .sol

Definicja struktury przyrządu LED – test1.sol

```
$file:test1.sol
begin
load_mesh mesh_inf=test1.msh
include file=test1.mater
  include file=test1.doping
output sol_outf=test1.out
```

Plik **.msh** będzie załadowany do symulatora.

Różne pliki zawierające informacje materiałowe będą dołączone do danych wejściowych.

Definicja podstawowej nazwy plików z danymi wyjściowymi.

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Plik typu .sol

Definicja struktury przyrządu LED – test1.sol

Definicja 1D trybu symulacji.

```
newton_par damping_step=5. max_iter=100 print_flag=3
use_sor max_iter=3000 print_sor=noprint
init_wave &&
  length= 0.2000E+03 backg_loss=500. &&
  boundary_type=[2 2 1 1] init_wavel= 0.8300E+00 mirror_ref=0.32 &&
  wavel_range=[ 0.8100E+00 0.8500E+00]
```

Definicja warunków granicznych do prowadzenia światła oraz krytycznych parametrów przyrządu (length, mirror reflectivity, background losses, etc...)

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Plik typu .sol

Definicja struktury przyrządu LED – test1.sol

Newton model ustala początkowe parametry przyrządu przy równowadze temperaturowej i jest to pierwszy wymagany krok symulacji.

Newton model definiuje przyrząd przy dodanych potencjałach.

Zmienne określają do których kontaktów przyłożone jest napięcie oraz jakie są parametry tego napięcia.

```
equilibrium
newton_par damping_step=1. print_flag=3
scan var=voltage_1 value_to= -0.1345E+01 print_step= 0.1345E+01 &&
   init_step= 0.2689E+00 min_step=1.e-5 max_step=0.5
scan var=current_1 value_to= 0.2500E+03 print_step= 0.2500E+03 &&
   init_step= 0.2500E+01 min_step=1.e-5 max_step= 0.2500E+02
end
```

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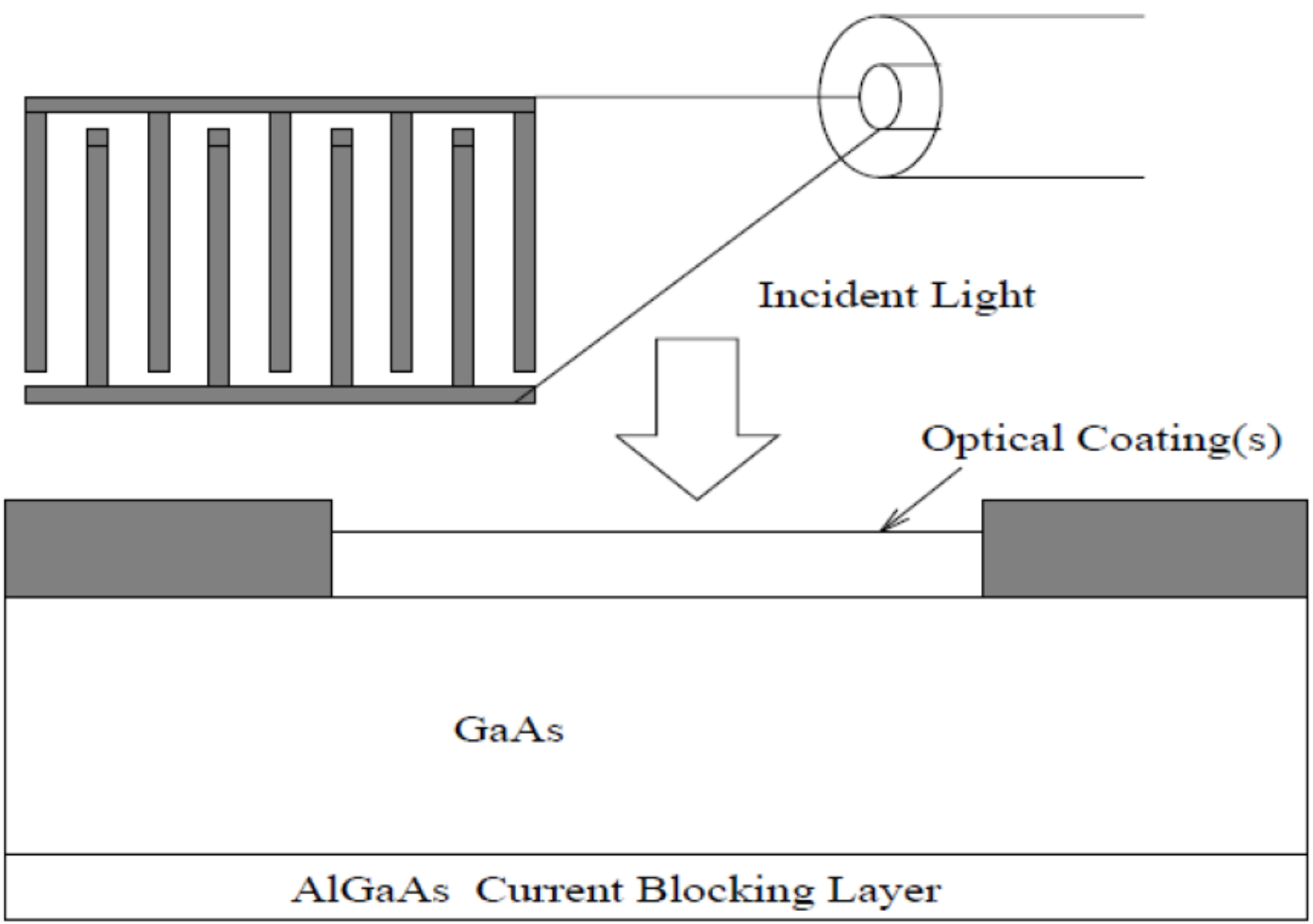
Crosslight Software Inc.

http://crosslight.com/

Struktura detektora MSM

Definicja struktury przyrządu – przekrój



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Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .layer struktury MSM

Definicja struktury przyrządu – plik msm.layer

```
begin_layer
$
column column_num=1 w=0.5 mesh_num=4 r=0.8 &&
column column_num=2 w=1.5 mesh_num=19 r=-1.3 &&
xpoint_left=yes xpoint_right=yes
column column_num=3 w=0.5 mesh_num=4 r=1.2 &&
xpoint_left=yes
$
$ The lower current blocking layer.
$
layer_mater macro_name=algaas var1=0.3 column_num=1
layer_mater macro_name=algaas var1=0.3 column_num=2
layer_mater macro_name=algaas var1=0.3 column_num=3
layer d=0.15 n=4 r=1. &&
n_doping1=1.e21 n_doping2=1.e21 n_doping3=1.e21 &&
xp2=1
$
$ The main part of the GaAs MSM.
$
layer_mater macro_name=gaas column_num=1
layer_mater macro_name=gaas column_num=2
layer_mater macro_name=gaas column_num=3
layer d=0.5 n=8 r=0.8 &&
n_doping1=1.e21 n_doping2=1.e21 n_doping3=1.e21 &&
xp1=1 xp2=1
$
$ These are the two electrodes.
$
top_contact column_num=1 from=0 to=0.5 contact_num=1
top_contact column_num=3 from=0 to=0.5 contact_num=2
$
end_layer
```

Przy definicji większej ilości kolumn potrzebne są extra mesh lines. Do symulacji APSYS'em kontaktów Schottky'ego również potrzebna są extra mesh lines (aby bariera była dobrze zdefiniowana).

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http://crosslight.com/

Plik .sol struktury MSM część I

Definicja symulacji przyrządu – plik msm.sol

```
$file:msm.sol
$***********
begin
load_mesh mesh_inf=msm.msh
$
$ Equilibrium solution.
$
newton_par damping_step=5. var_tol=1.e-9 res_tol=1.e-9 &&
equilibrium
$
$ Ramp up the DC bias to 5 volts.
$
newton_par damping_step=1. var_tol=1.e-4 res_tol=1.e-4 &&
max_iter=30 opt_iter=15 stop_iter=15 print_flag=3
scan var=voltage_1 value_to=-5. print_step=5. &&
init_step=0.2 min_step=1.e-5 max_step=1.0
$
$ Turn on the Gaussian optical pulse with
$ pulse width of 4 ps.
$
scan var_num=2 2_variables=(time light) &&
value_to=50.D-12 print_step=50.D-12 &&
init_step=1.D-14 min_step=1.d-18 max_step=1.D-12 &&
relation=gaussian gsn_dt=4.e-12
$
$ We wait some more time until the MSM settles down.
$
scan var=time value_to=300.D-12 print_step=300.D-12 &&
init_step=1.D-12 min_step=1.d-15 max_step=10.D-12
```

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Plik .sol struktury MSM część II

```
$ **********incident light*****************
$
$ Define the incident light here. The profile is used
$ to block out the light for the area under the metal electrodes.
$
light_power incident_power=3.29e7 wavelength=0.82 &&
profile=(0.5, 2.0, 0.01, 0.01)
$
$ Put optical coatings on top of device, if you wish.
$ It may be used to optimize the optical interference inside
$ the MSM.
$
$optic_coating thickness=0.147 real_index=2.05 imag_index=0.
$
back_reflection real_refl=0. imag_refl=0.
output sol_outf=msm.out
$ *************************
$ Define the barrier potential for the Schottky contacts.
$
contact type=schottky barrier=-0.83 num=1
contact type=schottky barrier=-0.83 num=2
$
$ Include the doping and material description generated
$ by msm.layer.
$
include file=msm.doping
include file=msm.mater
$
$
$ Be sure to define the absorption for the GaAs layer. Otherwise
$ there will be no response from the detector
$
absorption value=1.1e6 mater=2
$
end
```

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Wstęp

- Struktura GaN LED
- Plik **.layer**
- Plik **.sol**

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Simulation software by:

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CROSSLIGHT Software Inc.

Simulation software by:

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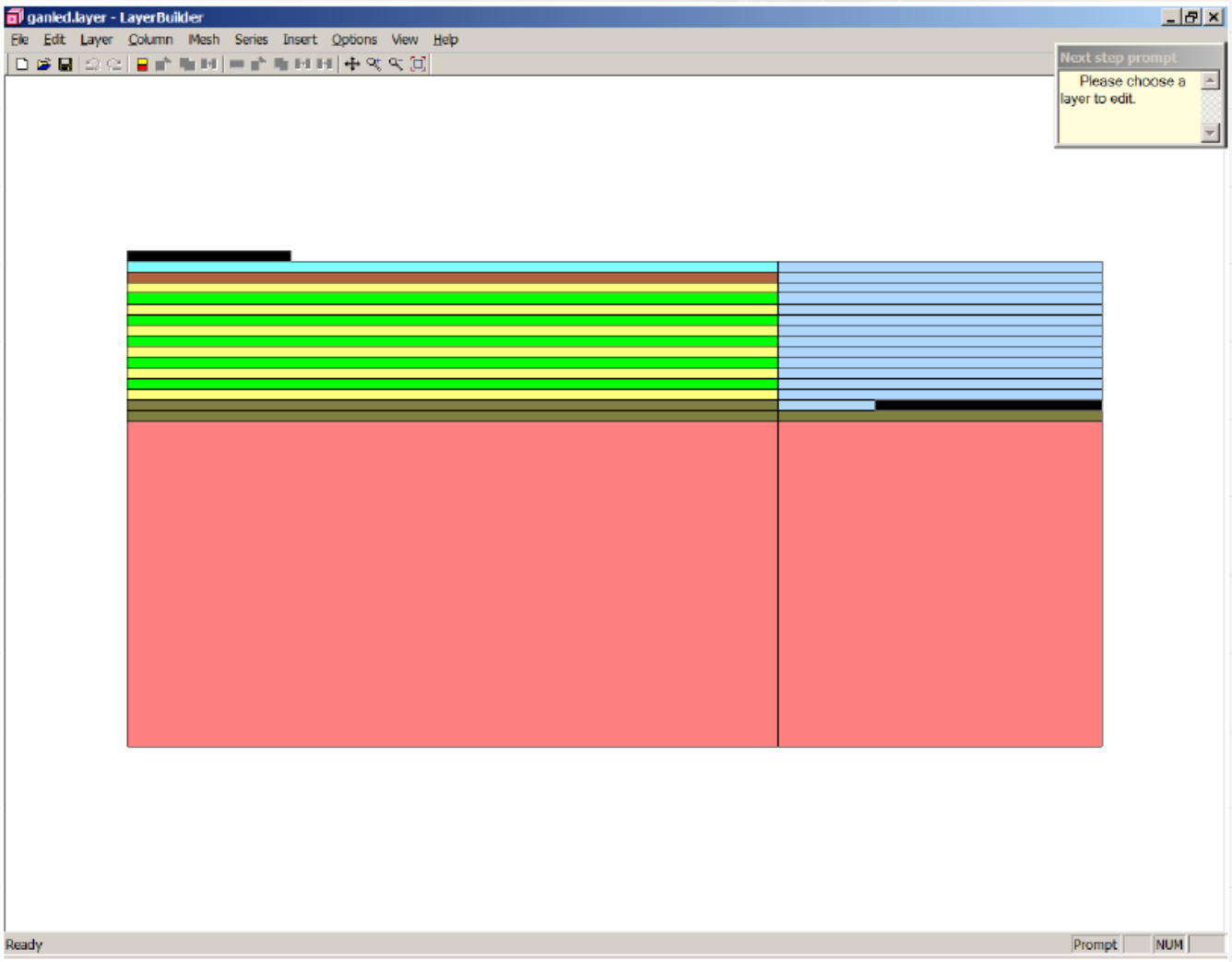
http://crosslight.com/

Struktura GaN LED

Definicja struktury przyrządu – przekrój



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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .layer

Definicja struktury przyrządu – ganled.layer cz. I

```
begin_layer
$
$ this has been moved to ganled.sol
$ set_polarization ref_column=1 screening=0.5
column column_num=1 w=200 mesh_num=10 r=0.85
column column_num=2 w=100 mesh_num=8 r=1.15
top_contact column_num=1 from=0.0 to=50 contact_num=2
top_contact column_num=2 from=30 to=100 contact_num=1
$
layer_mater macro_name=sapphire column_num=1
layer_mater macro_name=sapphire column_num=2
layer d=100. n=8 r=0.7
layer_mater macro_name=algan var1=0 column_num=1 var_symbol1=x
layer_mater macro_name=algan var1=0 column_num=2 var_symbol1=x
layer d=2.5 n=8 r=0.8 n_doping1=5e24 n_doping2=5e24
layer_mater macro_name=algan var1=0 column_num=1 var_symbol1=x
layer_mater macro_name=void column_num=2
layer d=0.5 n=5 r=0.8 n_doping1=5e24
```

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Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .layer

Definicja struktury przyrządu – ganled.layer cz. II

```
$ MQW region
include file=ganled.bar
include file=ganled.qw
include file=ganled.bar
include file=ganled.qw
include file=ganled.bar
include file=ganled.qw
include file=ganled.bar
include file=ganled.qw
include file=ganled.bar
include file=ganled.qw
include file=ganled.bar
$ for superlattice, we use effective medium theory and anisotropic
$ mobility and thermal conductivity, 24 SL
layer_mater macro_name=algan var1=0.07 column_num=1 var_symbol1=x
layer_mater macro_name=void column_num=2
layer d=0.18 n=6 r=1.0 p_doping1=3e23
$p+
layer_mater macro_name=algan var1=0 column_num=1 var_symbol1=x
layer_mater macro_name=void column_num=2
layer d=0.015 n=4 r=1.0 p_doping1=1.2e24
$
end_layer
```

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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .layer

Definicja struktury przyrządu – ganled.qw & ganled.bar

ganled.bar

```
$
layer_mater macro_name=ingan var1=0.0 column_num=1 var_symbol1=x &&
n_doping=3.e23
layer_mater macro_name=void column_num=2 n_doping=3.e23
layer d=0.015 n=12 r=-1.4
```

ganled.qw

```
$
layer_mater macro_name=ingan var1=0.11 &&
column_num=1 active_macro=InGaN/InGaN &&
avar1=0.11 avar2=0. &&
avar_symbol1=xw avar_symbol2=xb var_symbol1=x
layer_mater macro_name=void column_num=2 active_macro=void
layer d=0.0022 n=8 r=-1.3
```

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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .sol

Definicja struktury przyrządu – ganled.sol cz. I

```
$file:ganled.sol
$ *******
begin
load_mesh mesh_inf=ganled.msh
output sol_outf=ganled.out
more_output qw_states=yes
$ *******
include file=ganled.doping
include file=ganled.mater
polarization_charge_model screening=0.5 vector=(0 1 0)
set_active_reg tau_scat=0.4e-13
modify_qw tail_energy=0.03
$self-consistent is necessary for polarization
self_consistent wave_range=0.005
```

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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .sol

Definicja struktury przyrządu – ganled.sol cz. II

```
$ Quantum transport model helps deal with thin,deep wells
q_transport
$ .mater shows superlattice is mater=9
mobility_xy dir=y factor_elec=0.2 mater=9
thermal_kappa_xy dir=y factor=0.1 mater=9
$ n-layer mobility may be enhanced due to SL design
max_electron_mob value=1 mater=2
min_electron_mob value=1 mater=2
$ Isothermal temperature at equilibrium
temperature temp=300
$ Turn on self-heating model
heat_flow damping_step=1
$ thermal_cond at contact here will determine self-heating
contact num=2 type=ohmic thermal_type=3 &&
thermal_cond=200. extern_temp=300
$ ----- initialize optical constatns------
set_wavelength wavelength=0.40 backg_loss=2000
$ Set LED model to "simple": we will calculate actual
$ extraction efficiency with raytracing later
led_simple wavelength=0.40 spectrum_num=50
$ Export raytracing data: convert 2D electrical simulation into
$ 3D raytracing boxes
export_raytrace ray3d_convert=yes
```

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CROSSLIGHT Software Inc.

Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik .sol

Definicja struktury przyrządu – ganled.sol cz. III

```
$$
start solving
$
newton_par damping_step=5. max_iter=100 print_flag=3
equilibrium
newton_par damping_step=1. print_flag=3
scan var=voltage_1 value_to=-10 init_step=0.1 max_step=0.5 &&
auto_finish=current_1 auto_until=1.0 auto_condition=above
scan var=current_1 value_to=600. print_step=150 &&
init_step=1 min_step=1e-3 max_step=30
end
```

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Simulation software by:

Crosslight Software Inc.

http://crosslight.com/

Plik z definicjami materiałów

crosslight.mac

Koniec wstępu