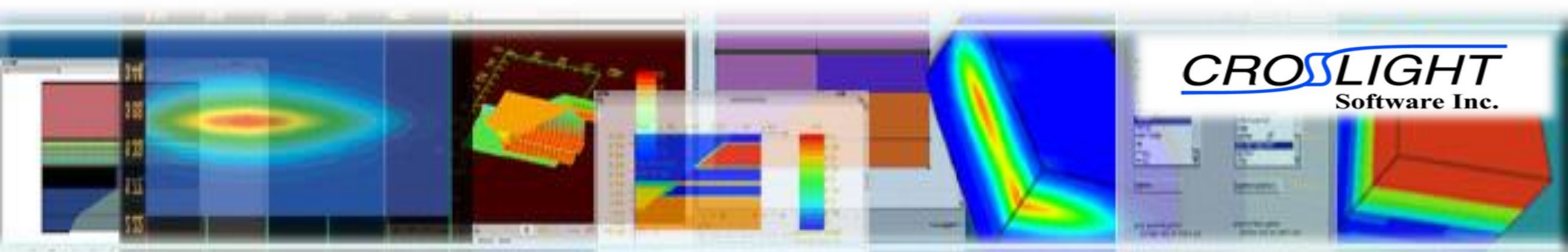

Simulation of Poly Grain Boundary Effects for LTPS Thinfilm Transistors

Crosslight Software Inc.

Contents

- Model: Grain boundary as trap region
- Process/Device Simulation
- Demo example
- Summary

Grain boundary region

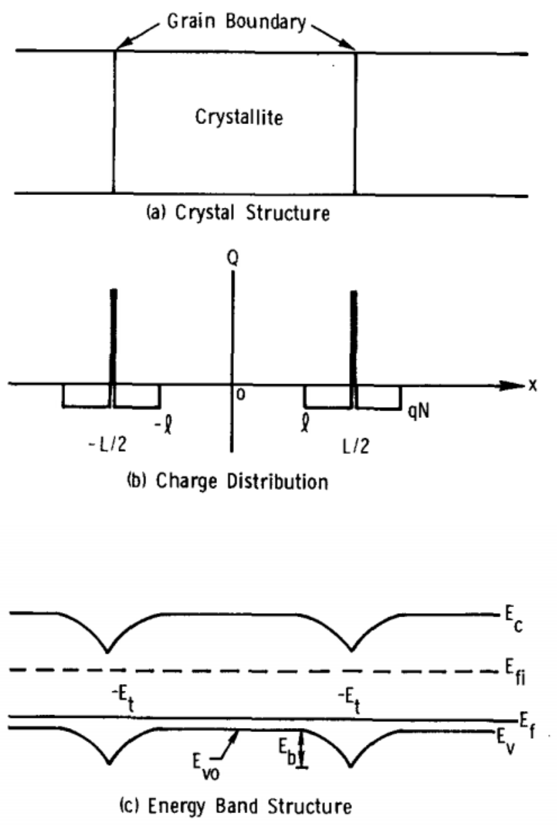

FIG. 6. (a) Model for the crystal structure of polysilicon films. (b) The charge distribution within the crystallite and at the grain boundary. (c) The energy band structure for polysilicon crystallites.

1975: experimental evidence that a mobility minima existed due to hole trapping at grain boundary

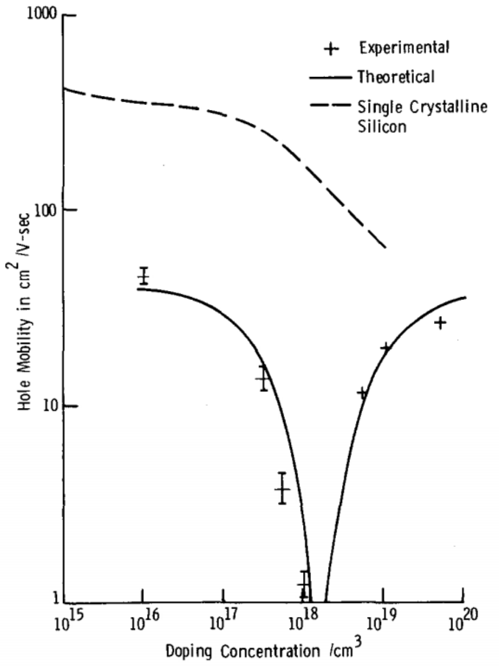

FIG. 2. Room-temperature hole Hall mobility vs doping concentration. The experimental result is plotted together with the theoretical solid curve. The broken line is for single-crystalline silicon.

The electrical properties of polycrystalline silicon films

John Y. W. Seto

5247 Journal of Applied Physics, Vol. 46, No. 12, December 1975

Poly grain boundary density of states (DOS)

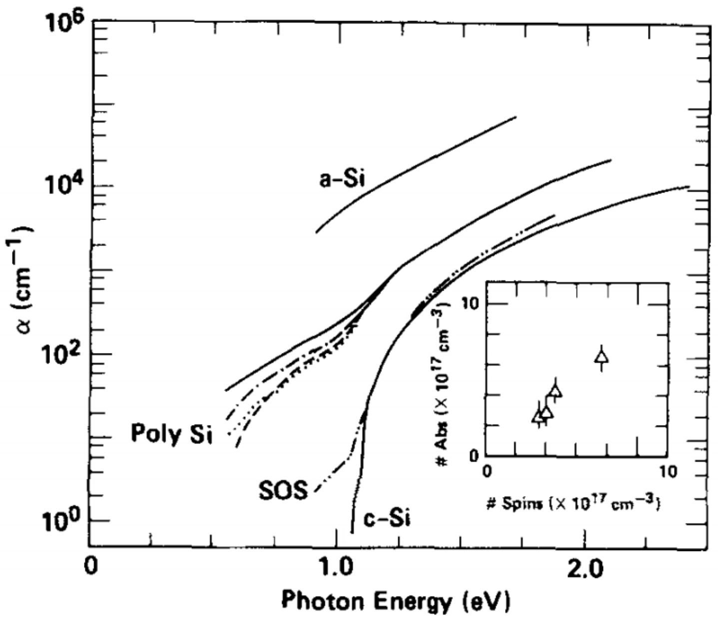

FIG. 1. Absorption vs photon energy for different intervals of atomic hydrogenation exposure. Evaporated amorphous silicon (*a*-Si) from Ref. 16. Fine grained polysilicon, unhydrogenated (solid), 60 min (dot-dash), 120 min (dash), 30 min (dotted), silicon-on-sapphire (SOS). Bulk crystallline silicon (*c*-Si) from Ref. 17. Inset shows the integrated density of optically absorbing defects with a cross section of 1.2×10^{-16} cm^{-2} (Ref. 8) vs the dangling bond spin density.

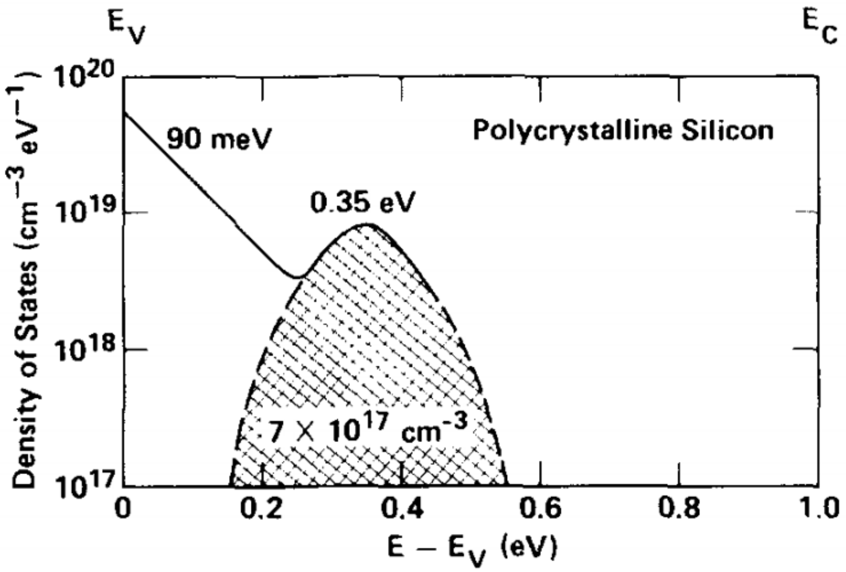

FIG. 3. Features of the grain boundary density of states derived from optical absorption and ESR measurements.

Density of gap states of silicon grain boundaries determined by optical absorption

Warren B. Jackson, N. M. Johnson, and D. K. Biegelsen

195 Appl. Phys. Lett. **43** (2), 15 July 1983

If we assume the region inside GB is crystal silicon, the DOS of GB would be very similar to a-Si

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Process incorporating GB

```
mater_define material_label=PI   mater_lib=PI_Mater
mater_define material_label=MoW  mater_lib=MoW
mater_define material_label=Mo   mater_lib=Mo
mater_define material_label=PolyGB   mater_lib=PolyGB
```

Define a new material named PolyGB

```
foreach v (1 to 8 step 1)
change_material  poly /PolyGB file=GBv.txt
end

# reflect the structure
struct mirror left

struct outf=07_final.str
```

Use of separate app such as Excel or Matlab to generate a series of data files (x/y coordinates) indicating the region of GB material. These can be controlled as uniformly sized or randomly sized.

GB1.txt:

```
0.195000000000000    -20.0000000000000
0.205000000000000    -20.0000000000000
0.205000000000000     20.0000000000000
0.195000000000000     20.0000000000000
0.195000000000000    -20.0000000000000
```

Grain boundary model

Four different continuous trap distributions, trap2 to trap5, are used to describe the exponential tails and Gaussian distributions.   Trap1 has been reserved for minority lifetime setting by our convention.

```
material type=semicond band_valleys=(6 1) &&
  el_vel_model=beta hole_vel_model=beta  &&
  traplevel2_model=expo_tail traplevel2_tail_side=conduction &&
  traplevel2_charge_type=acceptor &&
  traplevel3_model=expo_tail traplevel3_tail_side=valence &&
  traplevel3_charge_type=donor &&
  traplevel4_model=gaussian traplevel4_charge_type=acceptor &&
  traplevel5_model=gaussian traplevel5_charge_type=donor
```

Acceptor-like trap states near the conduction band edge (trap2)

Donor-like trap states near the valence band edge (trap3)

Acceptor-like Gaussian states in upper part of the bandgap (trap4)

Donor-like Gaussian states in the lower part of the bandgap (trap5)

Grain boundary model

Four different continuous trap distributions, trap2 to trap5, are used to describe the exponential tails and Gaussian distributions. Trap1 has been reserved for minority lifetime setting by our convention.

```
$ conduction band acceptor tail, integrated to bulk value
$ DOS(E)=trap_conc/tail*exp(-(Ec-E)/tail)
$
trap_conc_2 value=1.e23
traplevel_tail_2 value=0.015
trap_ncap_2 value=2.e-21
trap_pcap_2 value=5.e-20

$
$ valuence band side donor tail
$ DOS(E)=trap_conc/tail*exp(-(E-Ev)/tail)
$
trap_conc_3 value=1.e23
traplevel_tail_3 value=0.3
trap_ncap_3 value=5.e-20
trap_pcap_3 value=2.e-21
```

Grain boundary model

Four different continuous trap distributions, trap2 to trap5, are used to describe the exponential tails and Gaussian distributions. Trap1 has been reserved for minority lifetime setting by our convention.

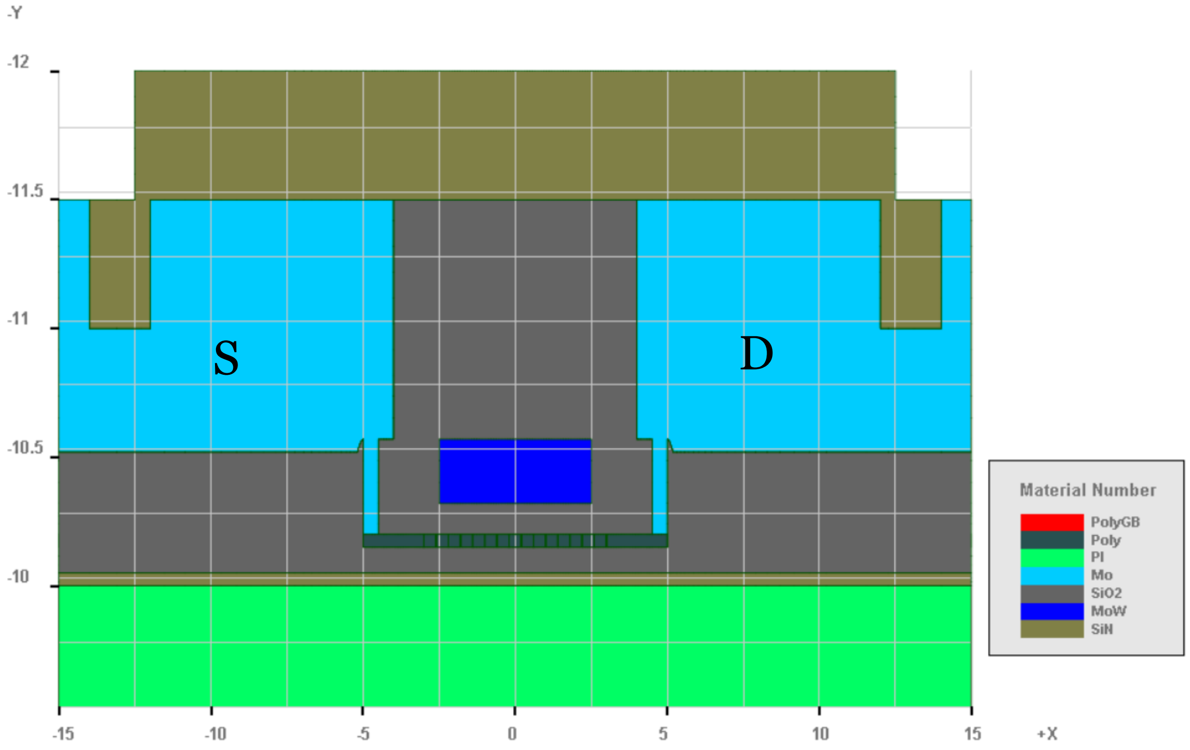
$ For gaussian DOS:
$ DOS(E)=trap_conc*/sig/sqrt(2*pi)*exp(-(E-Ep)**2/2/sig**2)
$ where Ep=peak energy level (trap_level), sig=standard deviation (stddev)
$

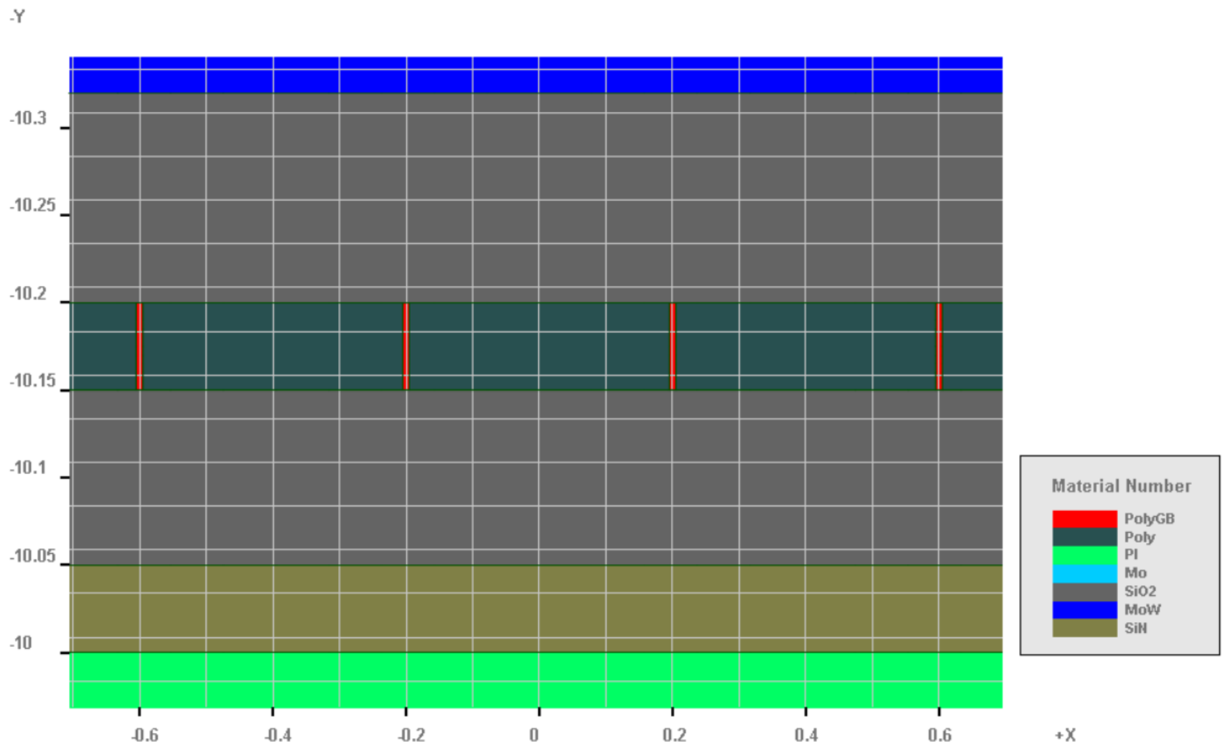
$ upper acceptor like gaussian from conduction bank
trap_conc_4 value=1.e23
trap_level_4 value=0.3
traplevel_stddev_4 value=0.15
trap_ncap_4 value=2.e-21
trap_pcap_4 value=5.e-20

$ lower donor like gaussian
trap_conc_5 value=1.e23
trap_level_5 value=0.8
traplevel_stddev_5 value=0.08
trap_ncap_5 value=5.e-20
trap_pcap_5 value=2.e-21

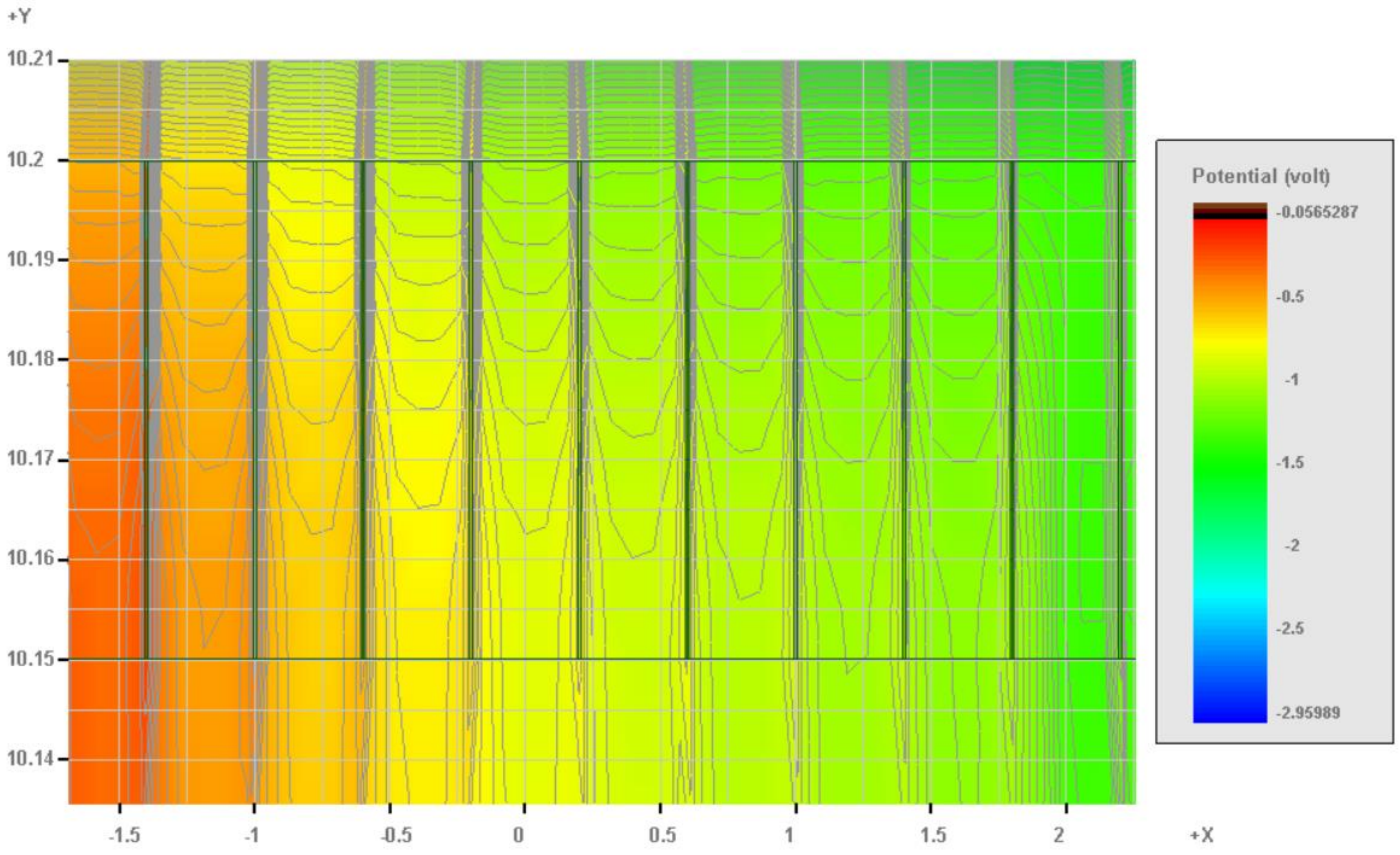
Contents

P-type LTPS TFT

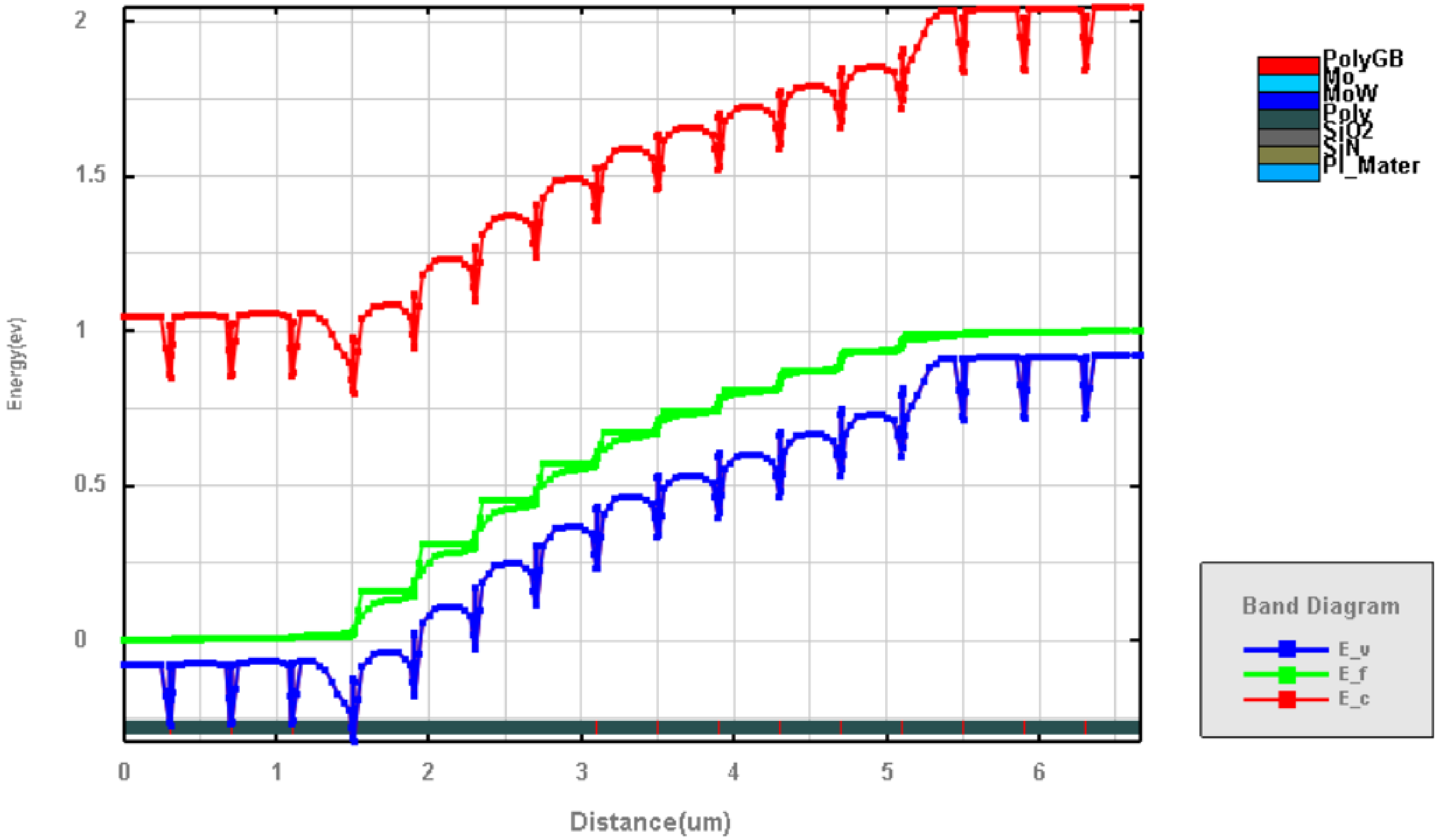




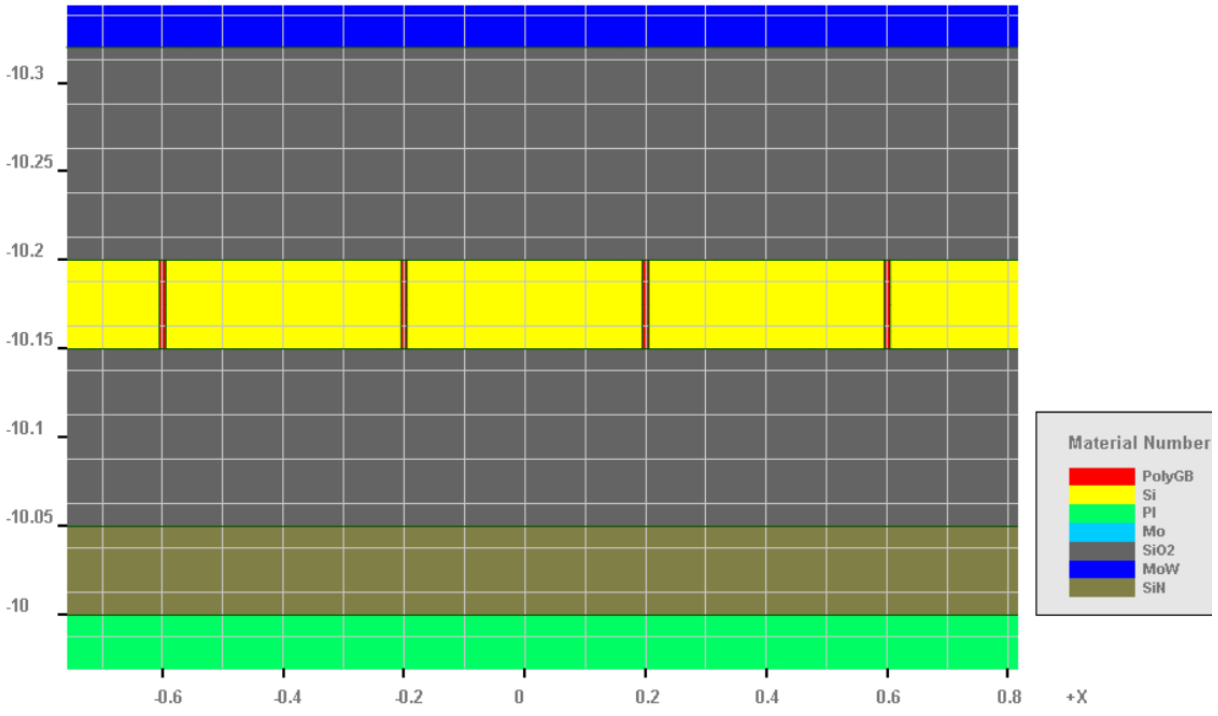
Potential distribution at LTPS channel at Vg=-6, Vd=-1

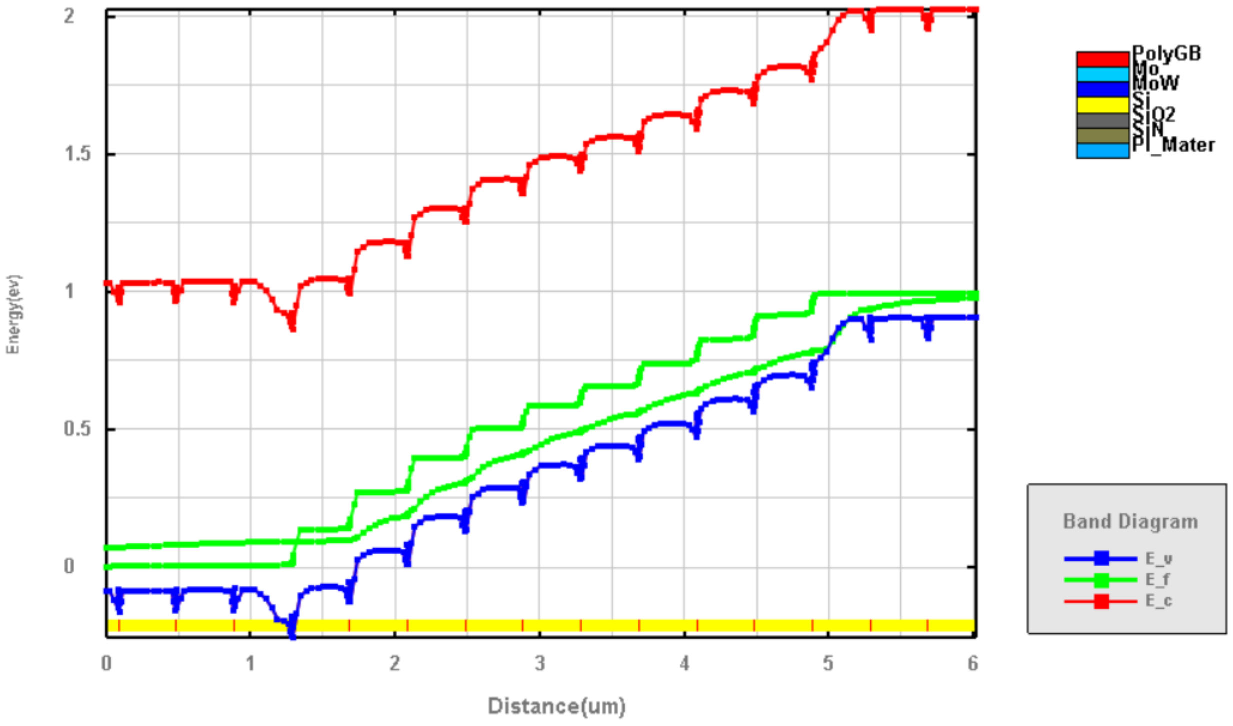


Band diagram along LTPS channel at Vg=-6, Vd=-1



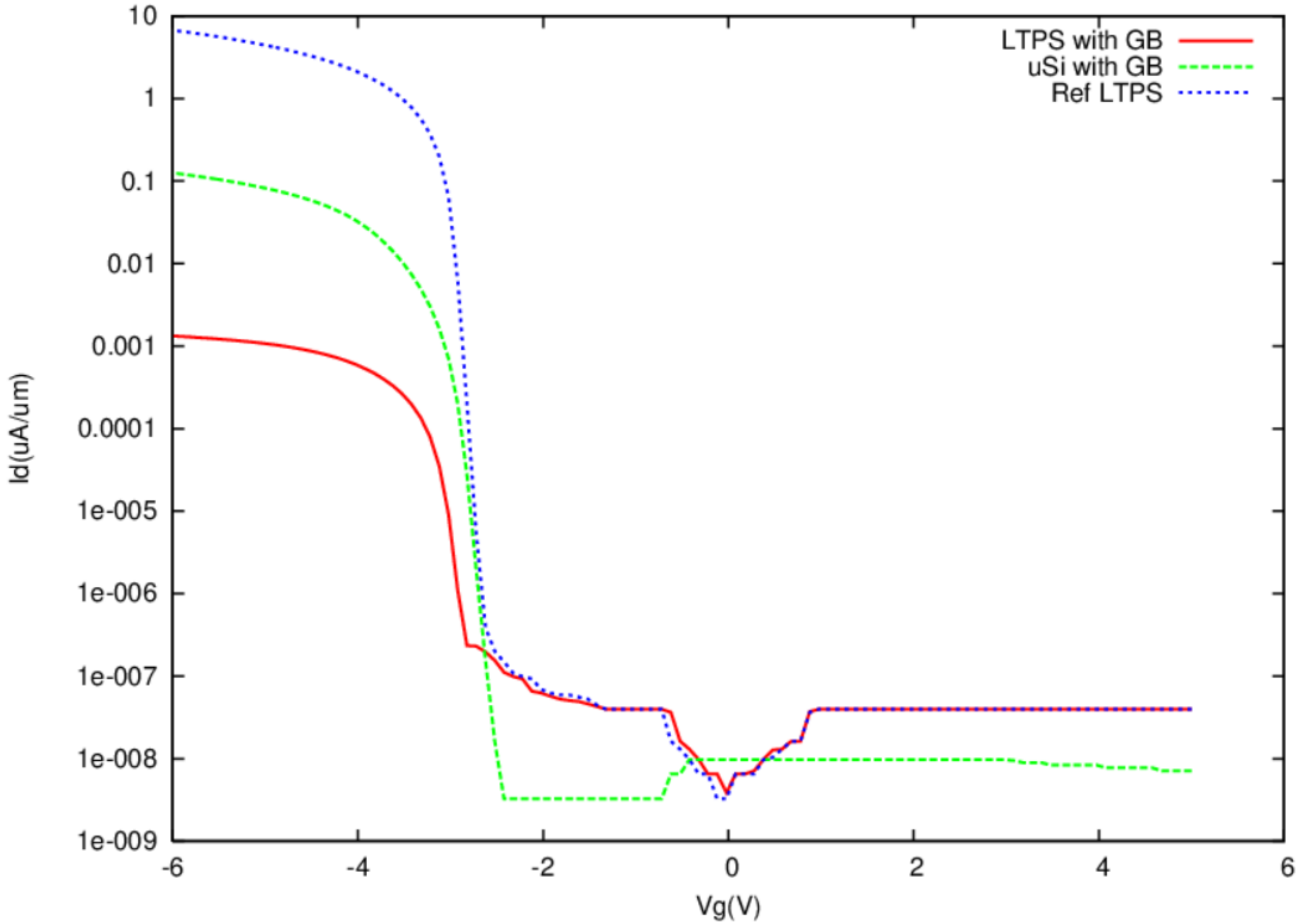
For comparison, uSi channel separated by poly grain boundary is simulated.





Vg=-6 Vd=-1

Comparison of Ref. LTPS (uniform poly with no GB), LTPS with GB and uSi with GB

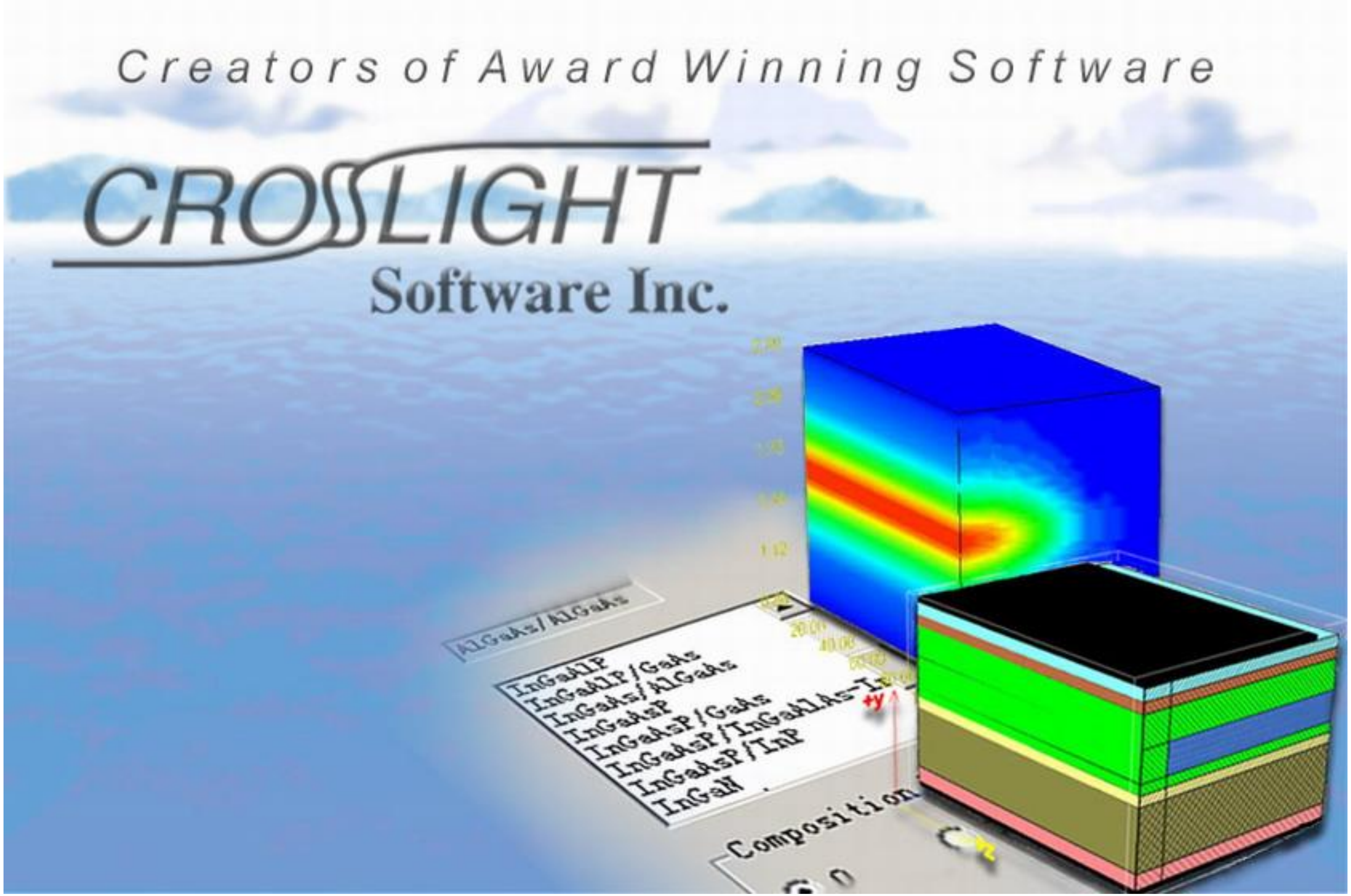


Micro-silicon region separated by GB can be used to mimic real LTPS in TFT structure.

Summary

- Sophisticated grain boundary model with DOS similar to a-Si established.
- Process can be modified to introduce GB
- uSi separated by GB is closer to uniform LTPS than uniform poly material separated by GB.

Thanks for your attention!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InGaAlP/GaAs
InGaAs/AlGaAs
InGaAsP
InGaAsP/GaAs
InGaAsP/InGaAlAs-In
InGaAsP/InP
InGaN
Composition