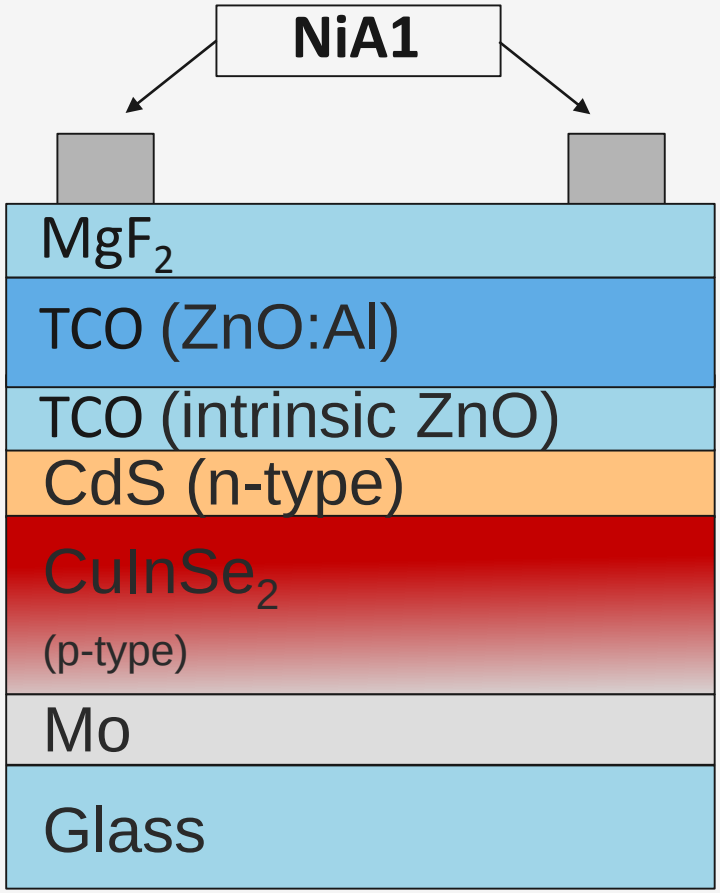
Thin-Film PV Technologies

CIGS PV Technology

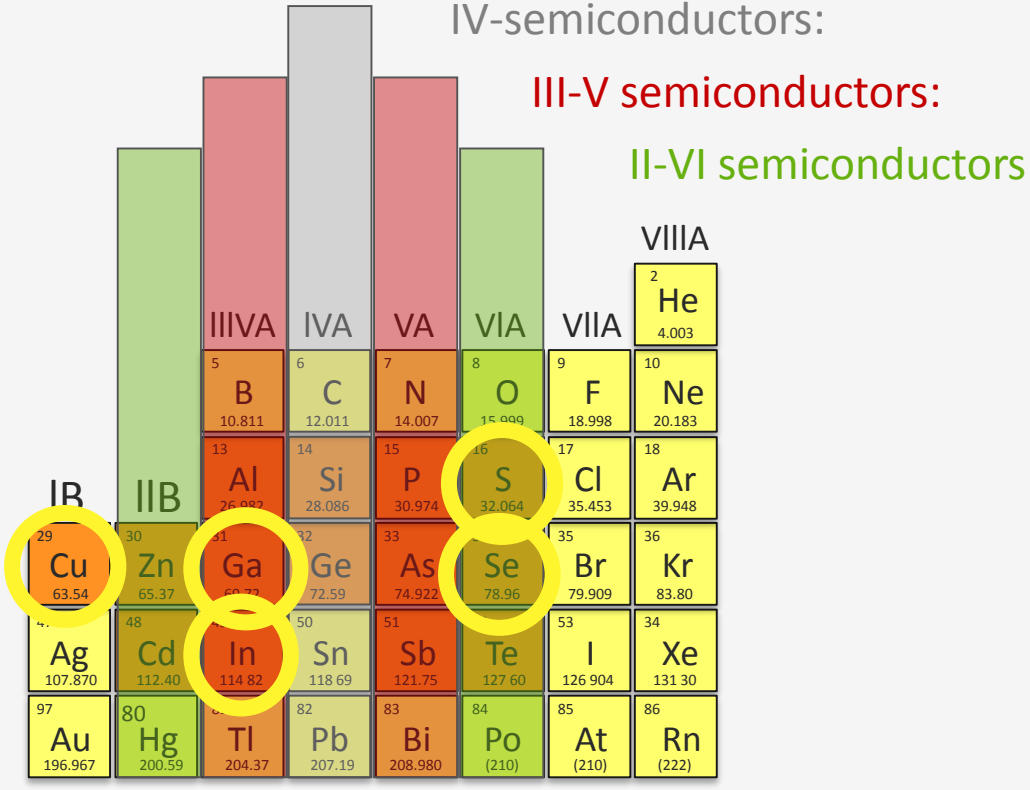
Week 5.3

Arno Smets

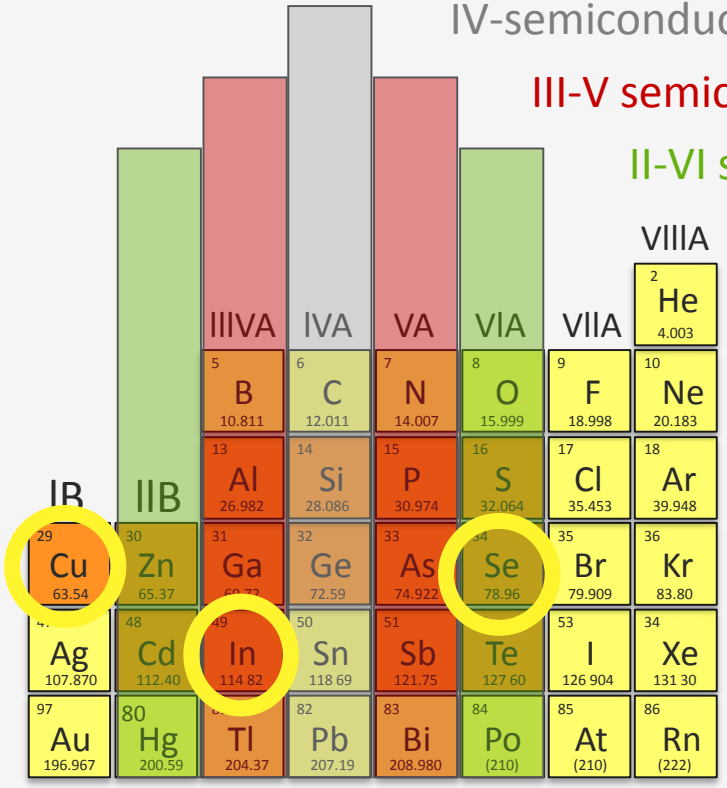
CIGS


NiA1
MgF_2
TCO (ZnO:Al)
TCO (intrinsic ZnO)
CdS (n-type)
$CuInSe_2$
(p-type)
Mo
Glass

CIGS

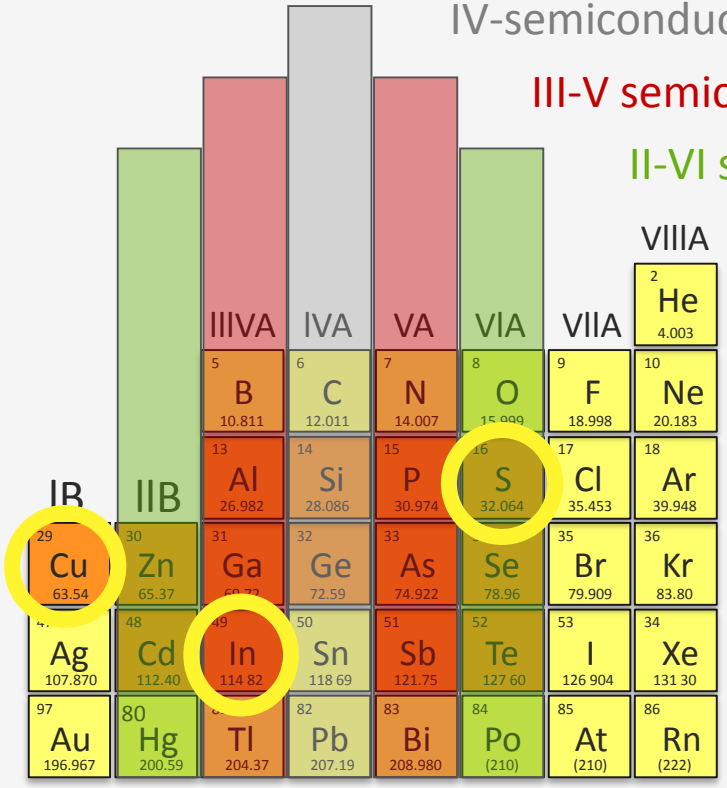

IV-semiconductors:
III-V semiconductors:
II-VI semiconductors
IB
IIB
IIIA
IVA
VA
VIA
VIIA
VIIIA
2 He 4.003
5 B 10.811
6 C 12.011
7 N 14.007
8 O
9 F 18.998
10 Ne 20.183
13 Al
14 Si 28.086
15 P 30.974
16 S 32.064
17 Cl 35.453
18 Ar 39.948
29 Cu 63.54
30 Zn 65.37
31 Ga
32 Ge 72.59
33 As 74.922
Se 78.96
35 Br 79.909
36 Kr 83.80
48 Cd 112.40
In 114 82
50 Sn 118 69
51 Sb 121.75
Te 127 60
53 I 126 904
34 Xe 131 30
Ag 107.870
97 Au 196.967
80 Hg 200.59
Tl 204.37
82 Pb 207.19
83 Bi 208.980
84 Po (210)
85 At (210)
86 Rn (222)

CIGS



$CuInSe_2$ E_{gap} = 1.0 eV

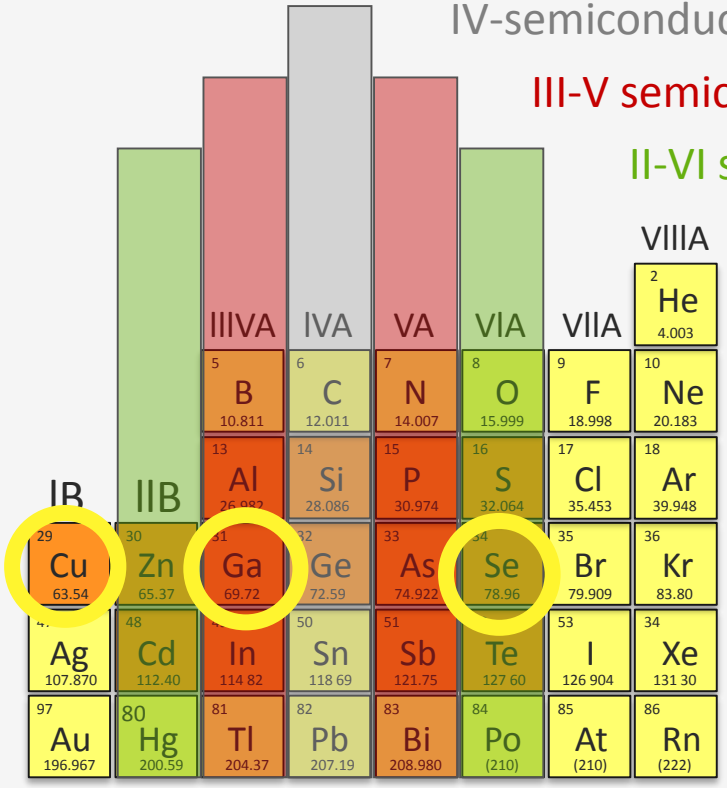
CIGS



$CuInSe_2$ E_{gap} = 1.0 eV

$CuInS_2$ E_{gap} = 1.5 eV

CIGS

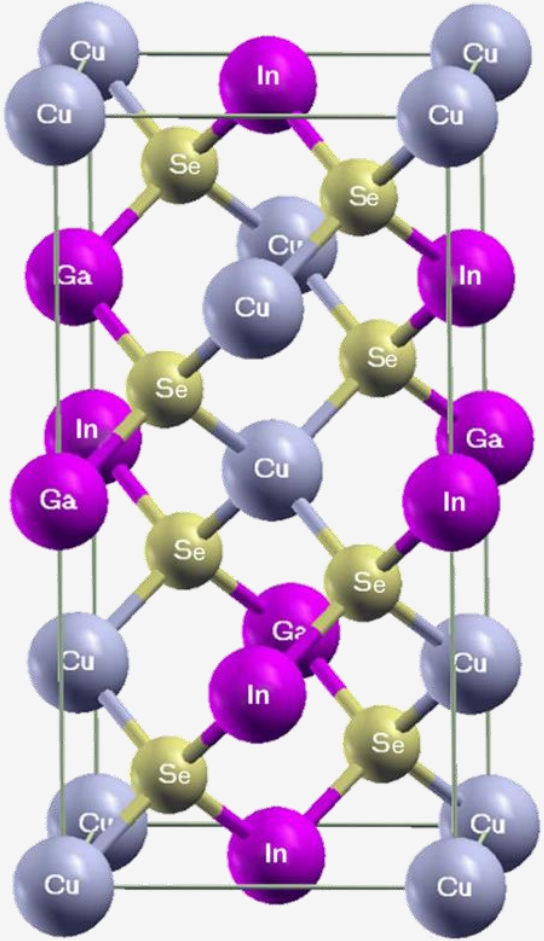


$CuInSe_2$ E_{gap} = 1.0 eV

$CuInS_2$ E_{gap} = 1.5 eV

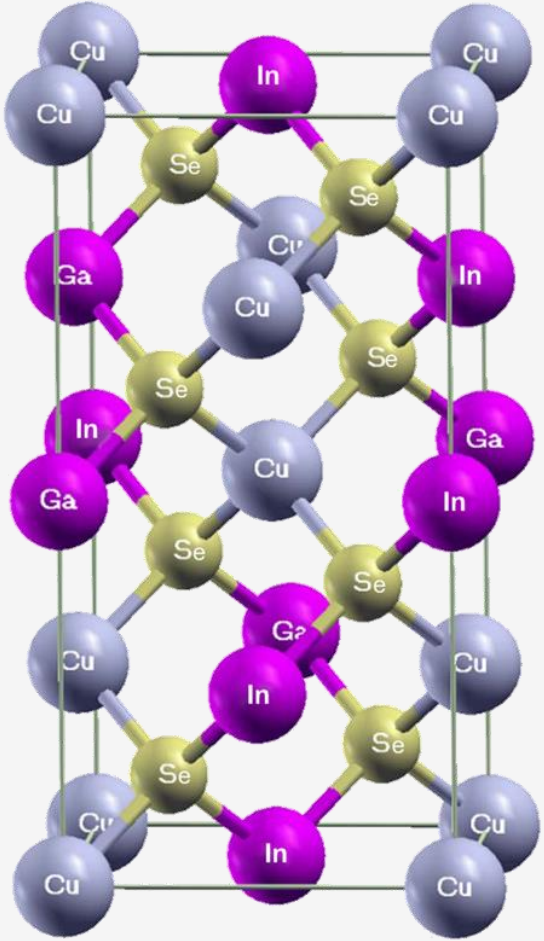
$CuGaSe_2$ E_{gap} = 1.7 eV

CIGS



Chen and Gong, PRB **75**, 205209 (2007)

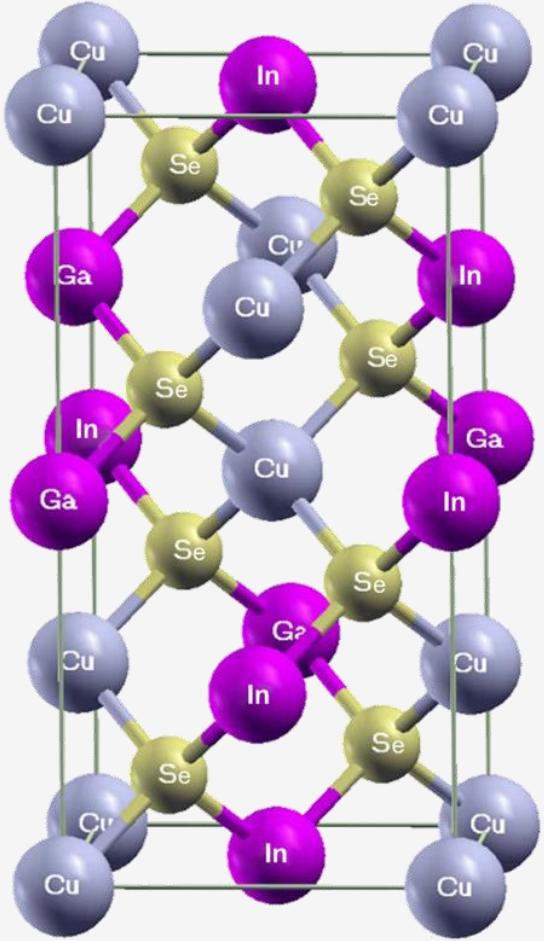
CIGS



CIS: $CuInSe_2$ E_{gap} = 1.0 eV

Chen and Gong, PRB **75**, 205209 (2007)

CIGS

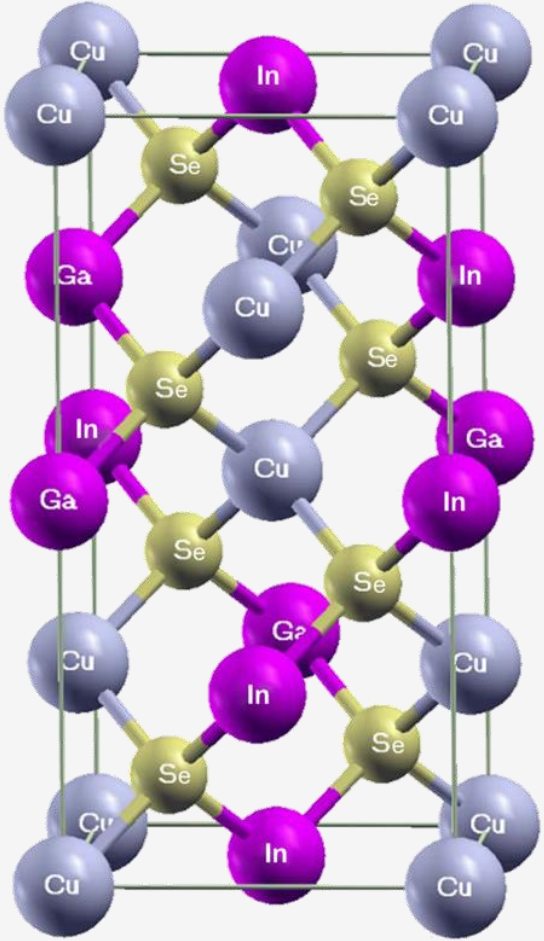


CIS: $CuInSe_2$ E_{gap} = 1.0 eV

$CuIn_xGa_{1-x}Se_2$ E_{gap} = 1.5 eV

Chen and Gong, PRB **75**, 205209 (2007)

CIGS



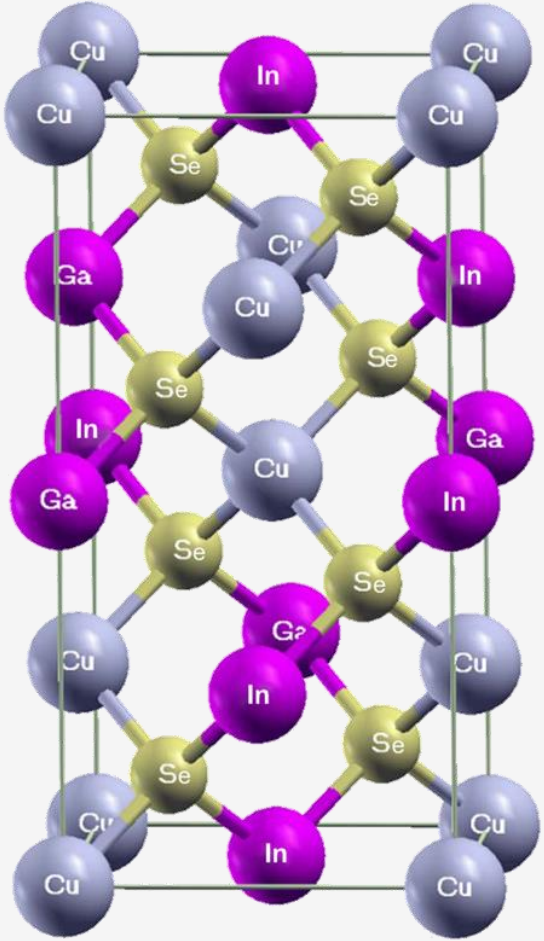
CIS: $CuInSe_2$ E_{gap} = 1.0 eV

$CuIn_xGa_{1-x}Se_2$ E_{gap} = 1.5 eV

x=0 $CuGaSe_2$ E_{gap} = 1.7 eV

Chen and Gong, PRB **75**, 205209 (2007)

CIGS



CIS: $CuInSe_2$ E_{gap} = 1.0 eV

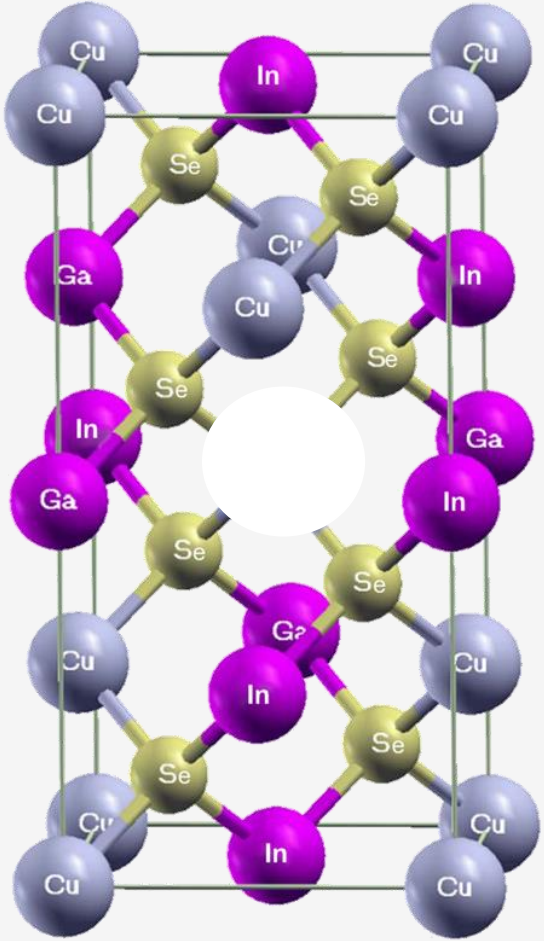
$CuIn_xGa_{1-x}Se_2$ E_{gap} = 1.5 eV

x=0 $CuGaSe_2$ E_{gap} = 1.7 eV

x=1 $CuInSe_2$ E_{gap} = 1.0 eV

Chen and Gong, PRB **75**, 205209 (2007)

CIGS



P-type

Cu deficiencies

Chen and Gong, PRB **75**, 205209 (2007)

CIGS solar cell

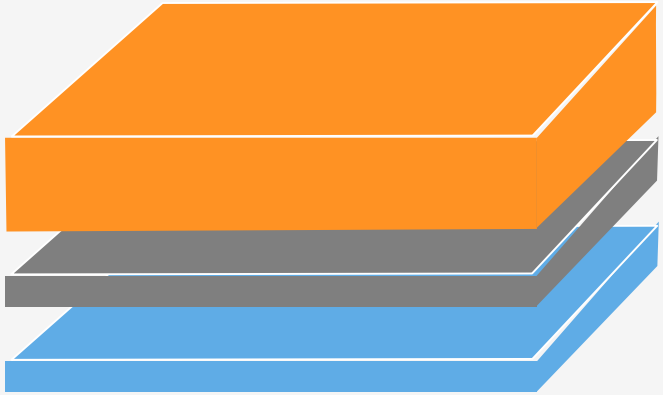
Glass

CIGS solar cell

Mo

Glass

CIGS solar cell

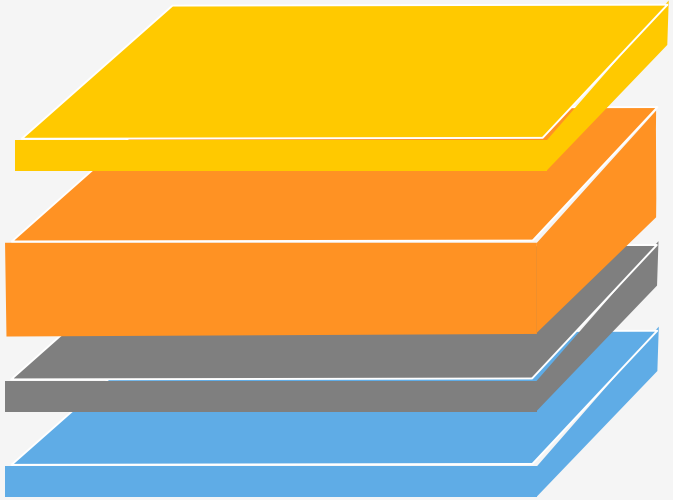


P-type CIGS

Mo

Glass

CIGS solar cell



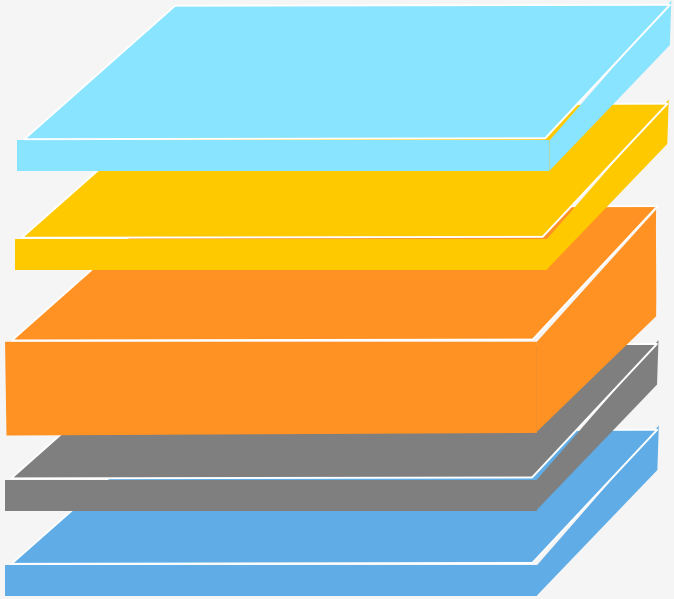
CdS Buffer

P-type CIGS

Mo

Glass

CIGS solar cell



i-ZnO

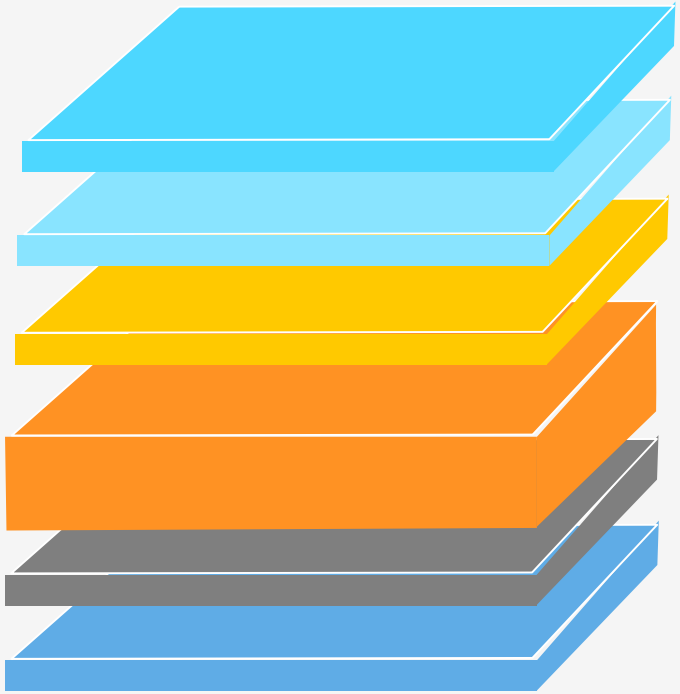
CdS Buffer

P-type CIGS

Mo

Glass

CIGS solar cell



Al-ZnO

i-ZnO

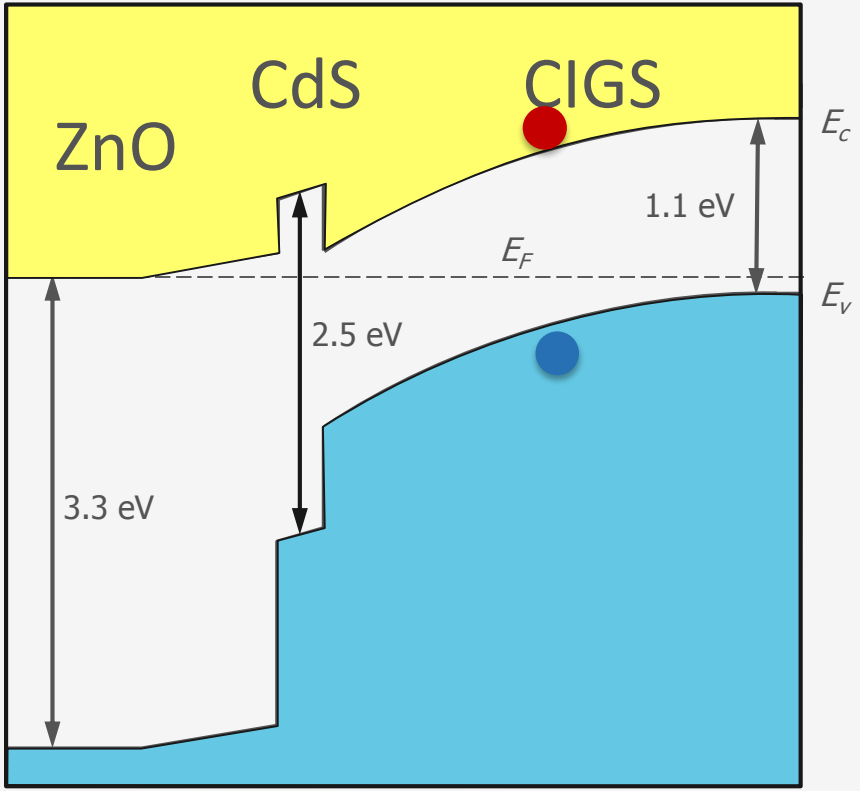
CdS Buffer

P-type CIGS

Mo

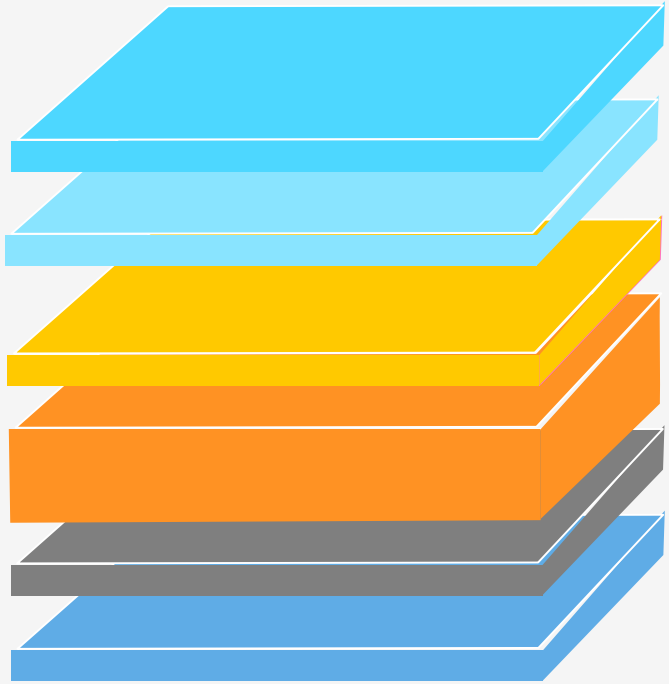
Glass

CI(G)S solar cell band diagram



CIGS solar cell

n-type CIGS
$Cu(InGa)_3Se_5$



Al-ZnO

i-ZnO

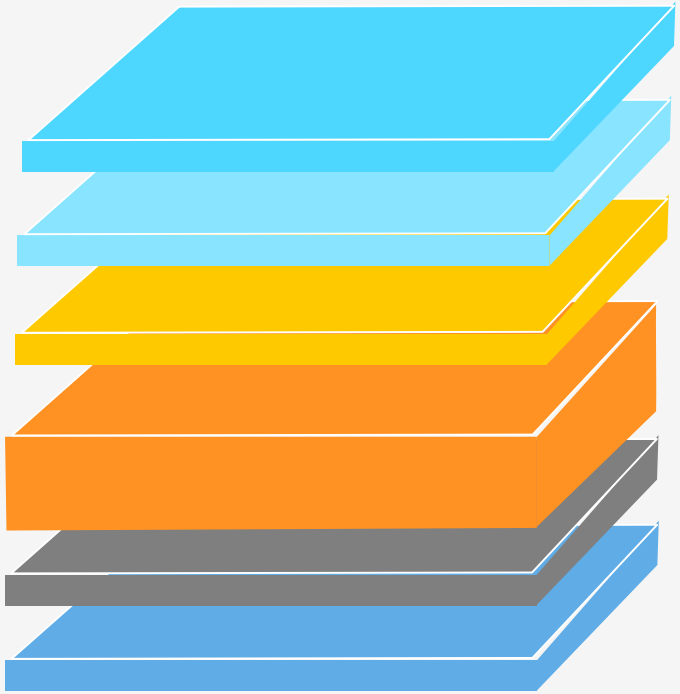
CdS Buffer

P-type CIGS

Mo

Glass

Role Sodium in CIGS solar cells



Al-ZnO

i-ZnO

CdS Buffer

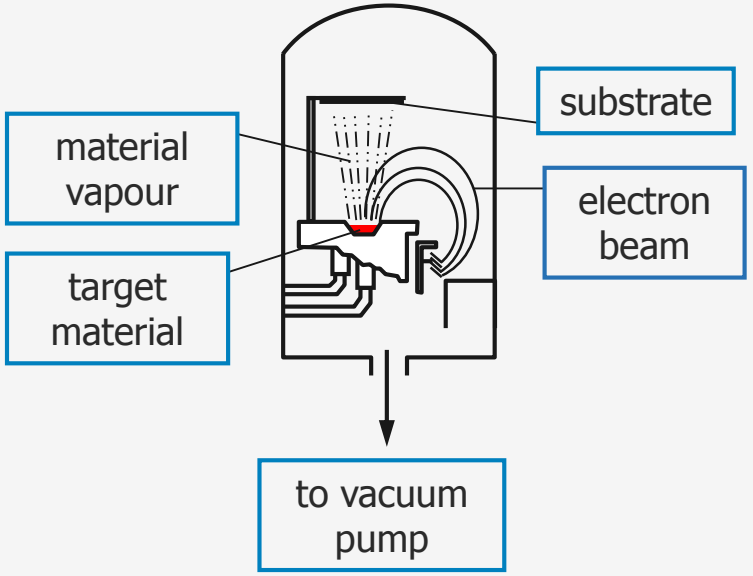
P-type CIGS

Mo

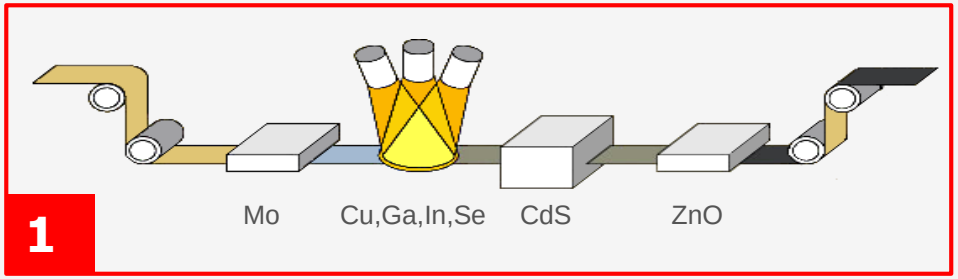
Glass

Sputtering deposition

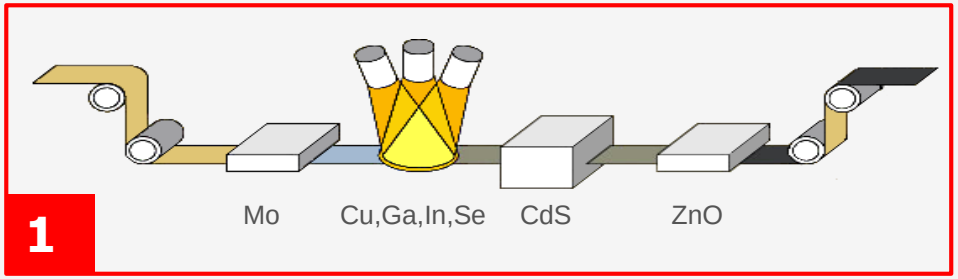
Co-evaporation

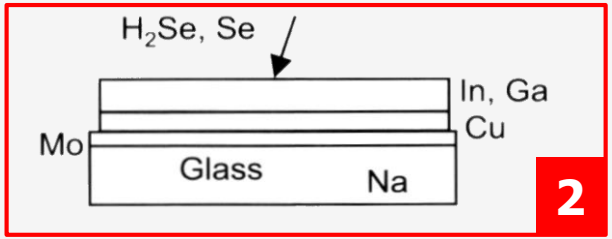


Processing CIGS solar cells

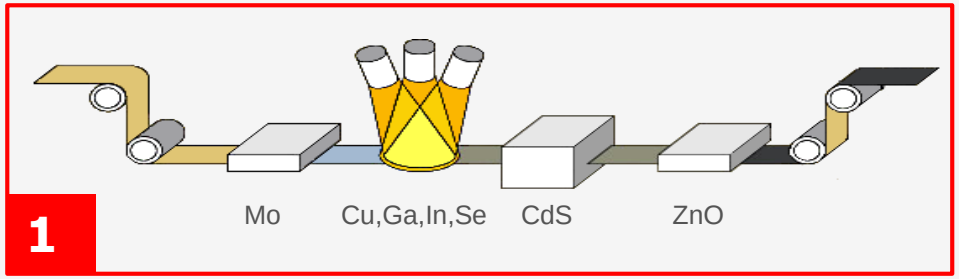


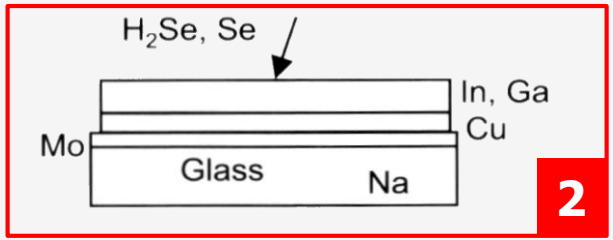
Processing CIGS solar cells

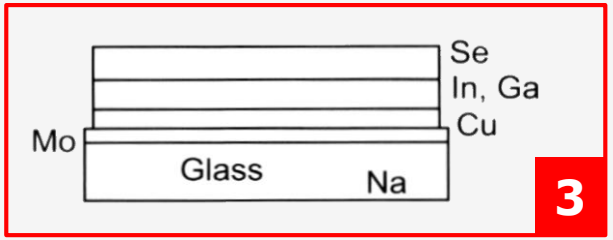




Processing CIGS solar cells







Labscale CIGS solar cells

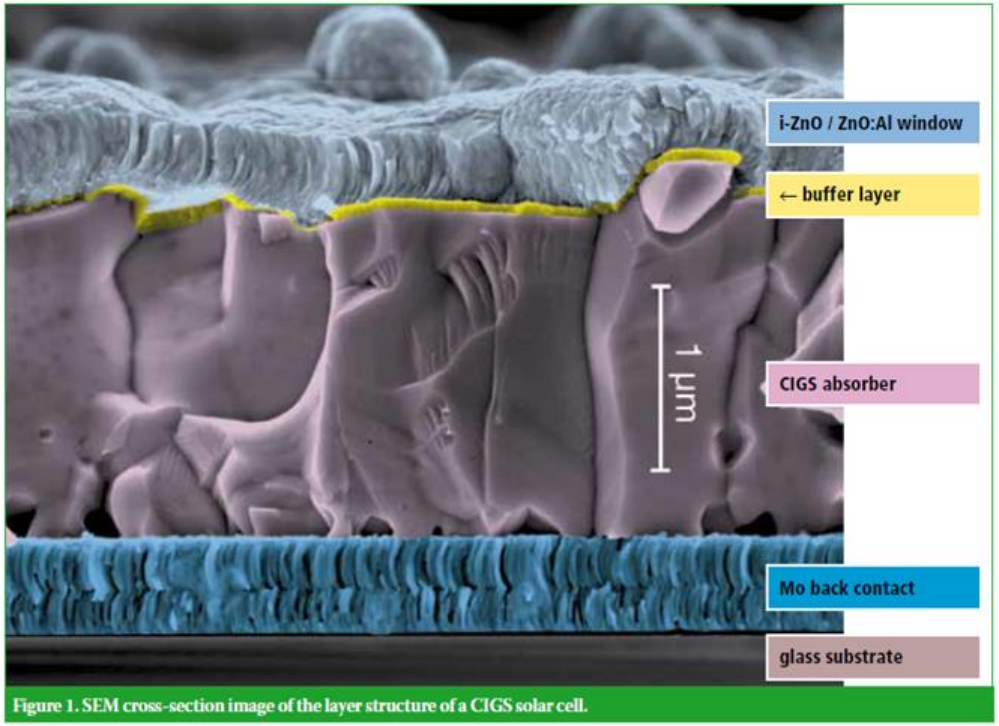


Figure 1. SEM cross-section image of the layer structure of a CIGS solar cell.

Glass

NREL:

Eff = 19.9 %

Voc ~ 700 mV

J_{sc} ~ 35-36 $mAcm^{-2}$

FF = 81 %

Labscale CIGS solar cells

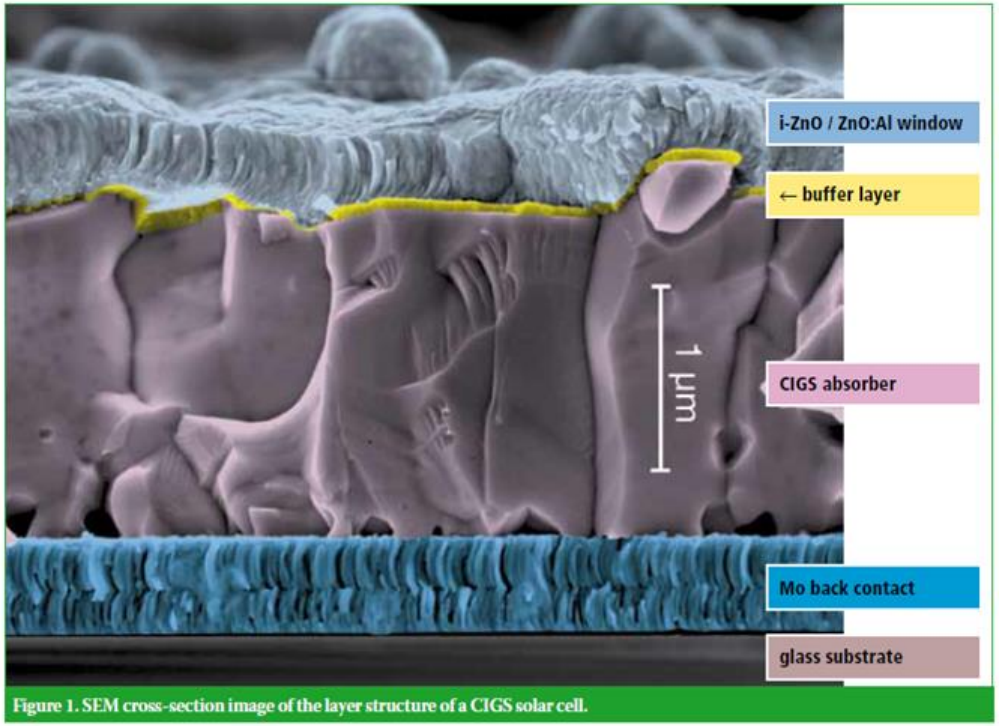


Figure 1. SEM cross-section image of the layer structure of a CIGS solar cell.

Glass

NREL:

Eff = 19.9 %

Voc ~ 700 mV

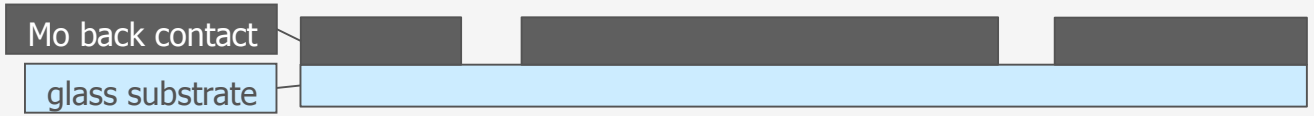
J_{sc} ~ 35-36 $mAcm^{-2}$

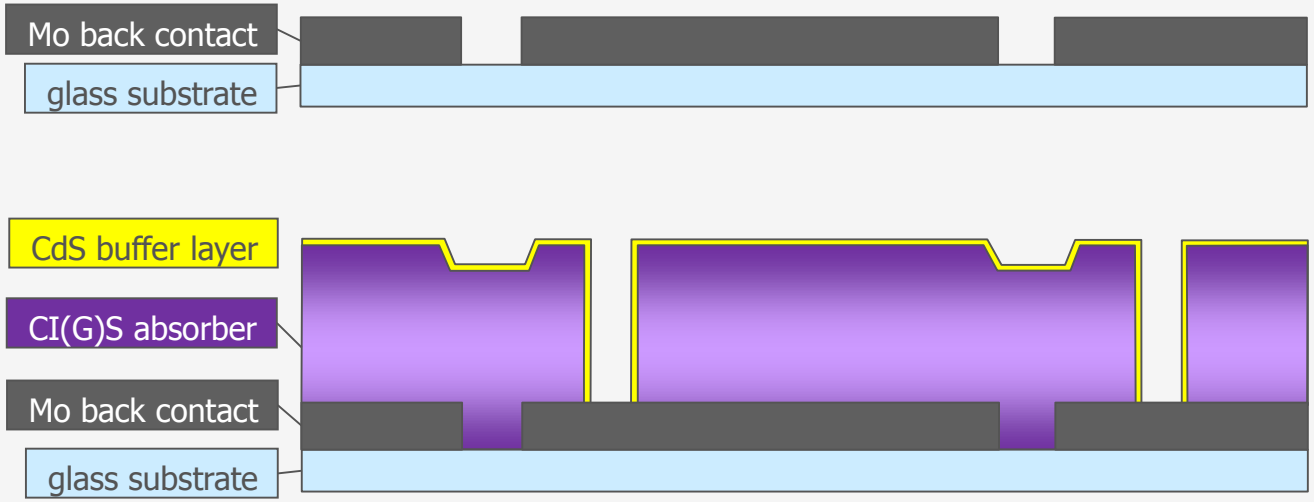
FF = 81 %

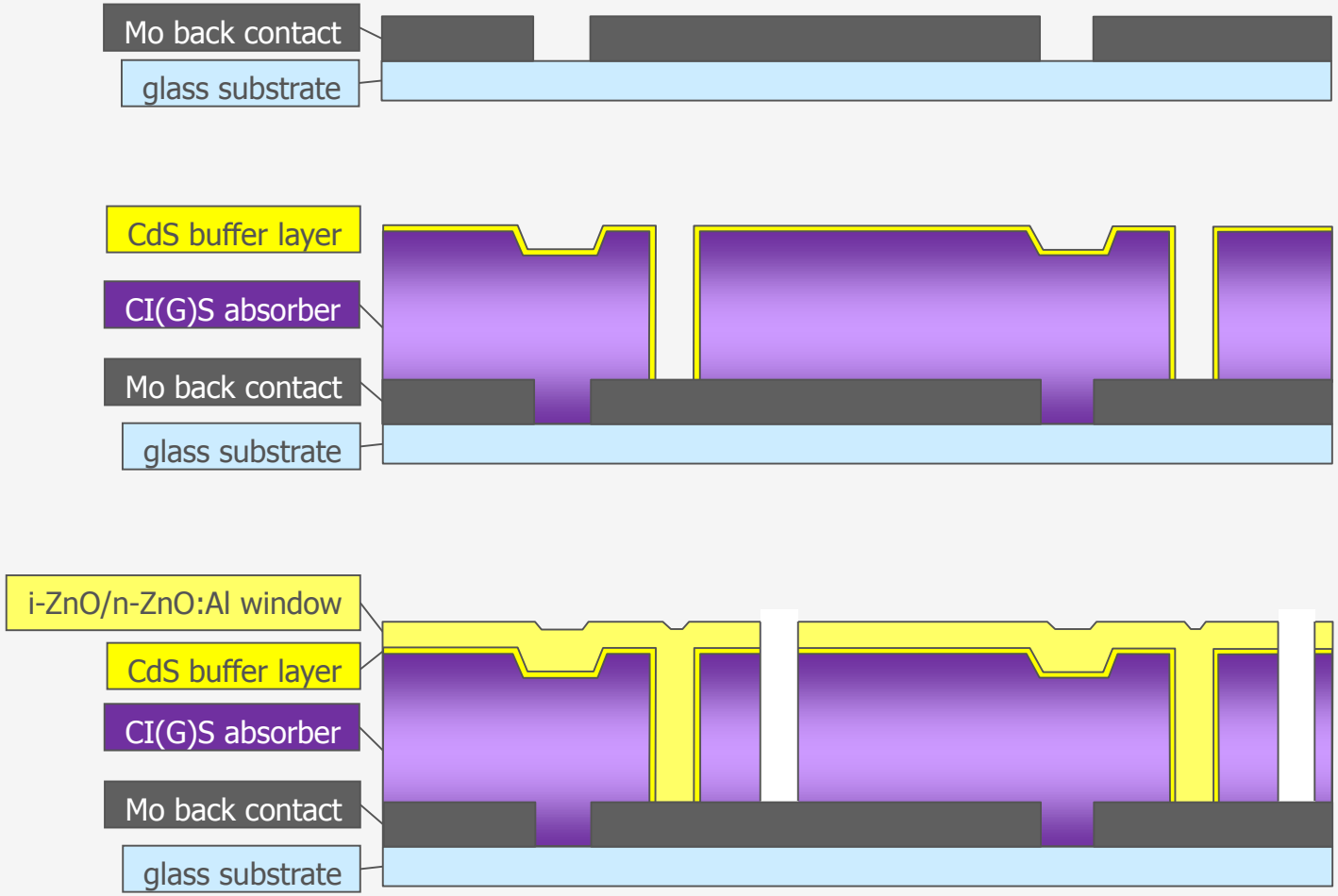
Flexible

SFL-MS:

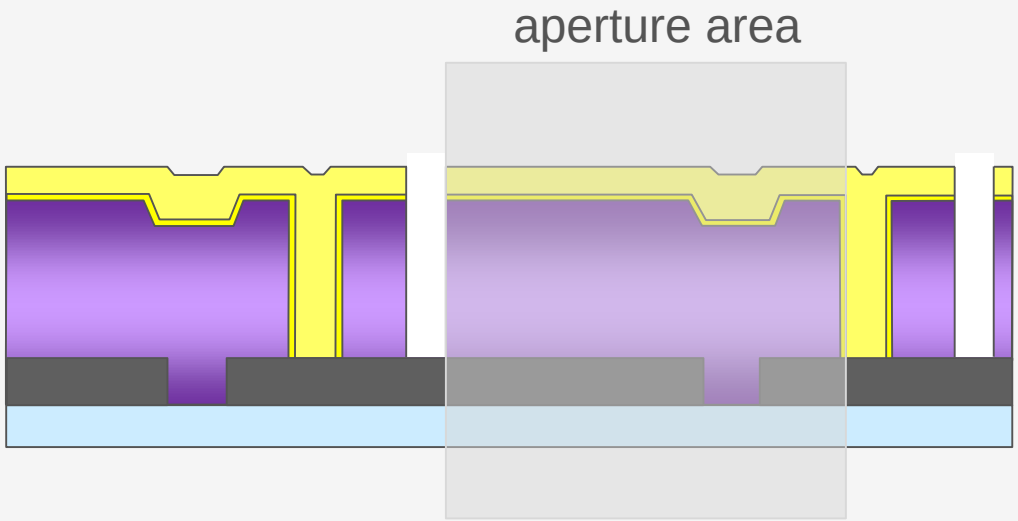
Eff: 20.4 %


Mo back contact
glass substrate

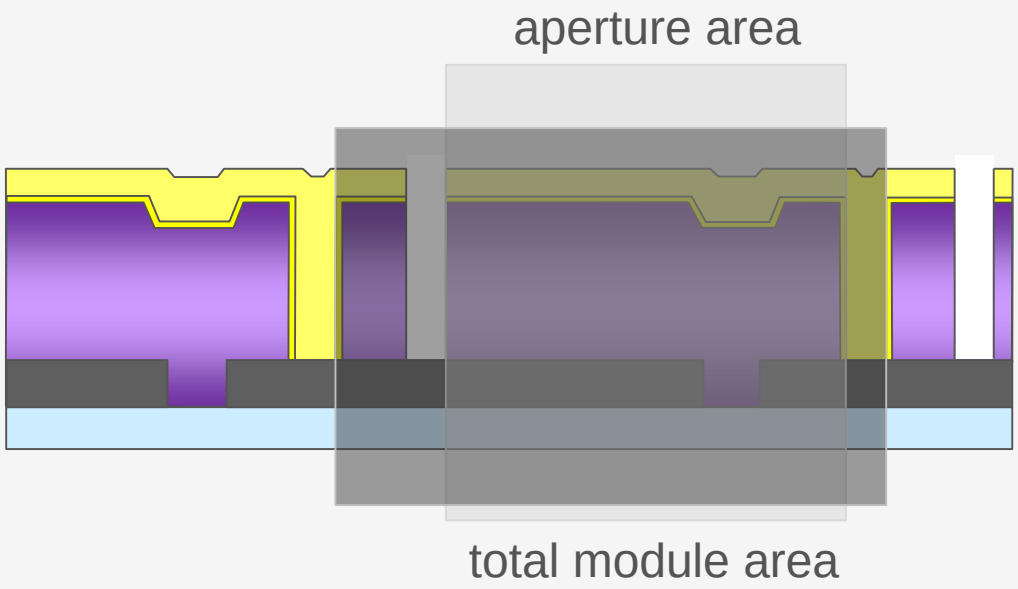

Mo back contact
glass substrate
CdS buffer layer
CI(G)S absorber
Mo back contact
glass substrate

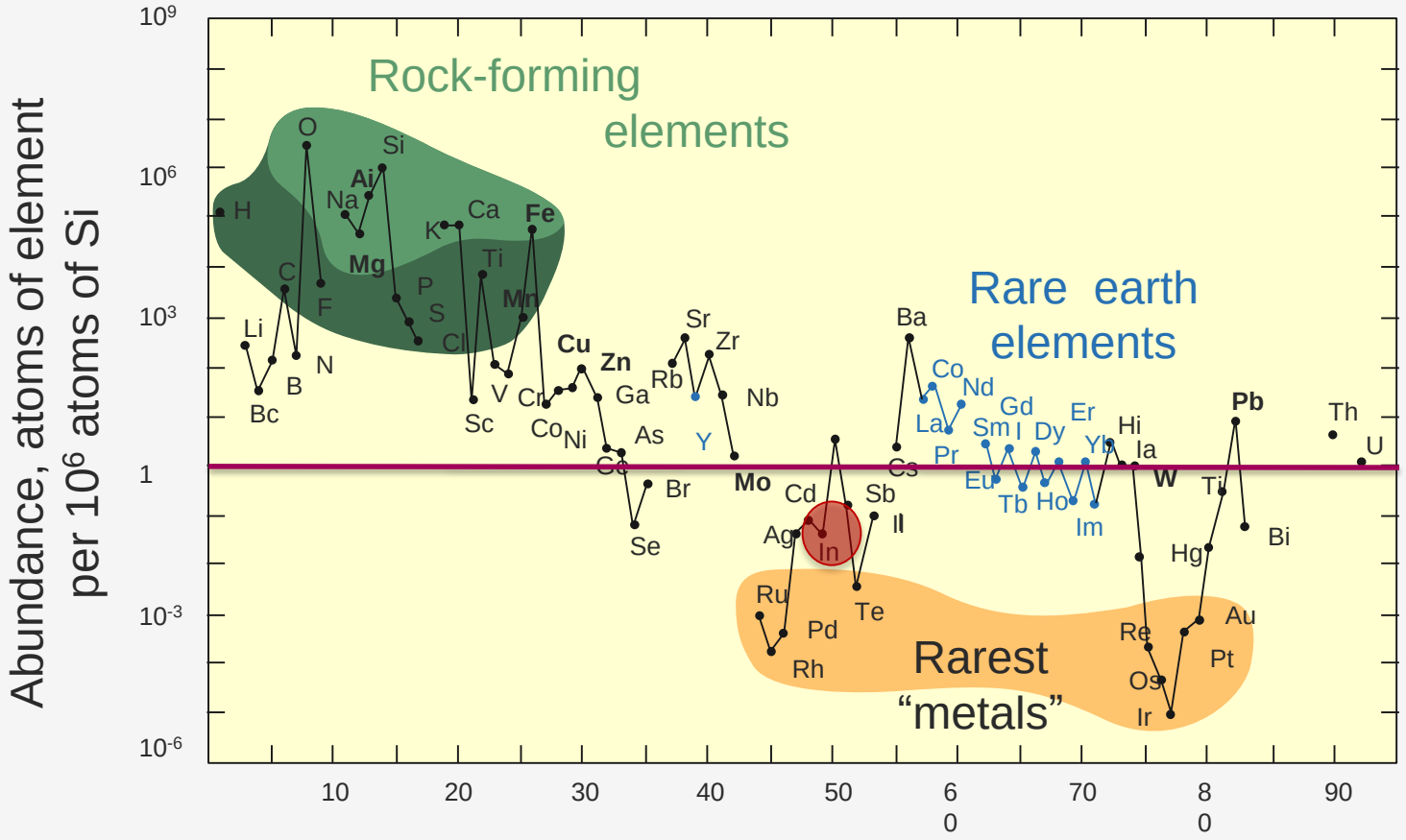

Mo back contact
glass substrate
CdS buffer layer
CI(G)S absorber
Mo back contact
glass substrate
i-ZnO/n-ZnO:Al window
CdS buffer layer
CI(G)S absorber
Mo back contact
glass substrate

Module Efficiency

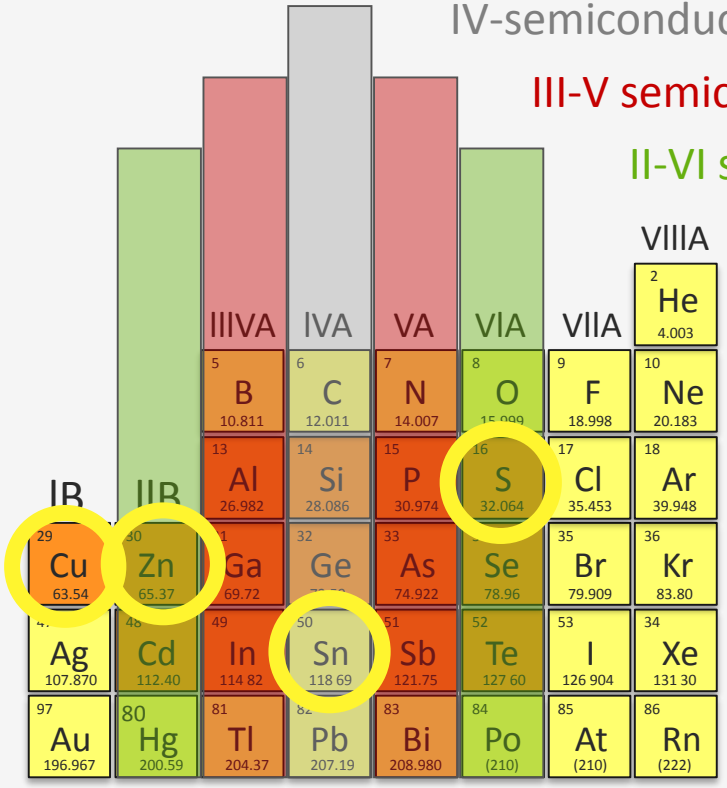


Module Efficiency




Abundance, atoms of element per 10^6 atoms of Si
10^9
10^6
10^3
1
10^-3
10^-6
Rock-forming elements
Rare earth elements
Rarest "metals"
H
O
Si
Al
Na
Mg
Ca
Fe
K
C
F
P
S
Cl
Ti
Mn
Li
N
B
Be
V
Cr
Co
Ni
Cu
Zn
Ga
Sr
Rb
Zr
Nb
Y
As
Se
Br
Mo
Cd
Ag
In
Sb
Te
Ru
Pd
Rh
Cs
Ba
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
Hf
W
Re
Os
Ir
Pt
Au
Hg
Tl
Pb
Bi
Th
U
10
20
30
40
50
60
70
80
90

CZTS (CuZnSnS)



CuZnSnS