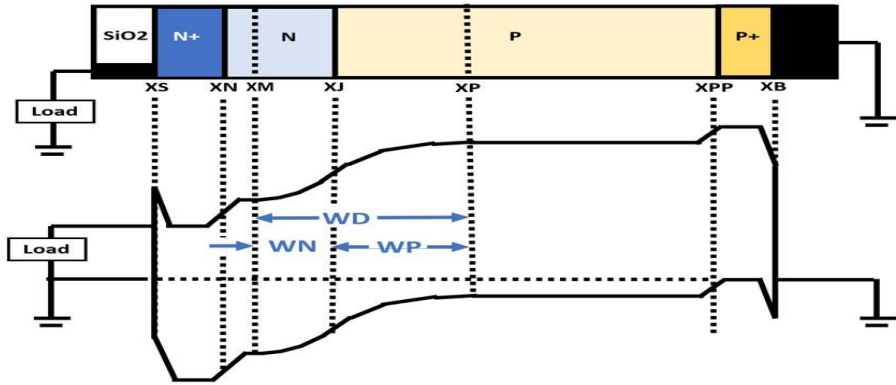
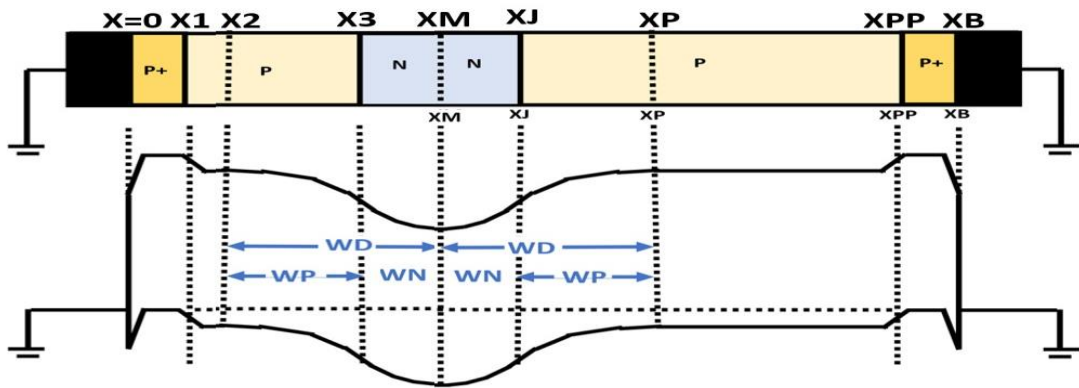


### (A) Conventional N+NP+ Single Junction Solar Cell



### (B) Bipolar Transistor P+PNPP+ Double Junction Solar Cell



シングルPN接合型太陽電池では、光電変換に寄与する空乏層幅(WD)は最大 $2\mu\text{m}$ が限界である事が簡単な計算で求まる。PN接合の深さ(XJ)の値は $0.1\mu\text{m}$ 以上の深さは意味を持たない。受光表面N+N層はできるだけ浅くする方が光電変換の効率アップに有利である。ダブル接合では2倍の空乏層が実現できる。

\*\*\*\*\*  
 重要な関係式  
 \*\*\*\*\*

$$DP = NV \cdot \exp(-VBP/kT) - NC \cdot \exp((VBP - EG)/kT);$$

$$DN = NC \cdot \exp(-VBN/kT) - NV \cdot \exp((VBN - EG)/kT);$$

$$VBPP = (EG + kT \cdot \log(NV/NC)) / 2;$$

$$VBNN = (EG + kT \cdot \log(NC/NV)) / 2;$$

\*\*\*\*\*

When  $VBPP = 0.567826$ ,  $DP = 0$ ;

When  $VBNN = 0.542174$ ,  $DN = 0$ ;

\*\*\*\*\*

\*\*\*\*\*

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\*\*\*\*\*

太陽電池を構成するPN接合内の空乏層領域内には十分な電界強度が必要である事に注目する。

また、不純物濃度の薄い真性半導体の方が空乏層幅は広がるが、実際には100Ωcm 程度が

限界である。従って不純物濃度は~140 per cubic μm 程度 (DP>140) である。

空乏層内での、光電子とホールが分離される為の電界強度を、

PN接合のバリア電圧  $V_B = kT = 0.0259 \text{ eV}$  として計算している。

シングルPN接合型太陽電池では空乏層幅は最大2 μmが限界である事が簡単な計算で求まる。

\*\*\*\*\*

VBPP=0.567826 VBN=0.542174

For { Vout=0.300000 ; VB>VBB=0.200000 ; WD>WDD=2.000000 ; }

VBP=0.317982	VBN=0.005422	VB=0.486596	DNP=130.371488	DP=130.373502	DN=8435694.814368	WD=2.199355	WN=0.000034
VBP=0.323661	VBN=0.005422	VB=0.480918	DNP=104.705673	DP=104.706973	DN=8435694.814368	WD=2.439792	WN=0.000030
VBP=0.317982	VBN=0.010843	VB=0.481174	DNP=130.371018	DP=130.373502	DN=6842398.750111	WD=2.187072	WN=0.000042
VBP=0.323661	VBN=0.010843	VB=0.475496	DNP=104.705371	DP=104.706973	DN=6842398.750111	WD=2.426003	WN=0.000037
VBP=0.317982	VBN=0.016265	VB=0.475752	DNP=130.370440	DP=130.373502	DN=5550037.274437	WD=2.174720	WN=0.000051
VBP=0.323661	VBN=0.016265	VB=0.470074	DNP=104.704998	DP=104.706973	DN=5550037.274437	WD=2.412137	WN=0.000046
VBP=0.317982	VBN=0.021687	VB=0.470331	DNP=130.369727	DP=130.373502	DN=4501771.216877	WD=2.162299	WN=0.000063
VBP=0.323661	VBN=0.021687	VB=0.464652	DNP=104.704538	DP=104.706973	DN=4501771.216877	WD=2.398191	WN=0.000056
VBP=0.317982	VBN=0.027109	VB=0.464909	DNP=130.368848	DP=130.373502	DN=3651496.933623	WD=2.149807	WN=0.000077
VBP=0.323661	VBN=0.027109	VB=0.459231	DNP=104.703971	DP=104.706973	DN=3651496.933623	WD=2.384165	WN=0.000068
VBP=0.317982	VBN=0.032530	VB=0.459487	DNP=130.367764	DP=130.373502	DN=2961818.629581	WD=2.137244	WN=0.000094
VBP=0.323661	VBN=0.032530	VB=0.453809	DNP=104.703272	DP=104.706973	DN=2961818.629581	WD=2.370058	WN=0.000084
VBP=0.317982	VBN=0.037952	VB=0.454065	DNP=130.366428	DP=130.373502	DN=2402403.659101	WD=2.124608	WN=0.000115
VBP=0.323661	VBN=0.037952	VB=0.448387	DNP=104.702410	DP=104.706973	DN=2402403.659101	WD=2.355867	WN=0.000103
VBP=0.317982	VBN=0.043374	VB=0.448644	DNP=130.364780	DP=130.373502	DN=1948648.470106	WD=2.111899	WN=0.000141
VBP=0.323661	VBN=0.043374	VB=0.442965	DNP=104.701347	DP=104.706973	DN=1948648.470106	WD=2.341592	WN=0.000126
VBP=0.317982	VBN=0.048796	VB=0.443222	DNP=130.362750	DP=130.373502	DN=1580596.518682	WD=2.099116	WN=0.000173
VBP=0.323661	VBN=0.048796	VB=0.437544	DNP=104.700037	DP=104.706973	DN=1580596.518682	WD=2.327233	WN=0.000154
VBP=0.317982	VBN=0.054217	VB=0.437800	DNP=130.360246	DP=130.373502	DN=1282060.563102	WD=2.086257	WN=0.000212
VBP=0.323661	VBN=0.054217	VB=0.432122	DNP=104.698422	DP=104.706973	DN=1282060.563102	WD=2.312787	WN=0.000189
VBP=0.317982	VBN=0.059639	VB=0.432378	DNP=130.357160	DP=130.373502	DN=1039910.734987	WD=2.073324	WN=0.000260
VBP=0.323661	VBN=0.059639	VB=0.426700	DNP=104.696431	DP=104.706973	DN=1039910.734987	WD=2.298254	WN=0.000231
VBP=0.317982	VBN=0.065061	VB=0.426957	DNP=130.353355	DP=130.373502	DN=843497.076397	WD=2.060314	WN=0.000318
VBP=0.323661	VBN=0.065061	VB=0.421278	DNP=104.693977	DP=104.706973	DN=843497.076397	WD=2.283633	WN=0.000283
VBP=0.317982	VBN=0.070483	VB=0.421535	DNP=130.348664	DP=130.373502	DN=684181.145510	WD=2.047227	WN=0.000390
VBP=0.323661	VBN=0.070483	VB=0.415857	DNP=104.690951	DP=104.706973	DN=684181.145510	WD=2.268923	WN=0.000347
VBP=0.317982	VBN=0.075904	VB=0.416113	DNP=130.342882	DP=130.373502	DN=554956.090506	WD=2.034064	WN=0.000478
VBP=0.323661	VBN=0.075904	VB=0.410435	DNP=104.687221	DP=104.706973	DN=554956.090506	WD=2.254124	WN=0.000425
VBP=0.317982	VBN=0.081326	VB=0.410691	DNP=130.335753	DP=130.373502	DN=450138.482200	WD=2.020824	WN=0.000585
VBP=0.323661	VBN=0.081326	VB=0.405013	DNP=104.682623	DP=104.706973	DN=450138.482200	WD=2.239236	WN=0.000521
VBP=0.317982	VBN=0.086748	VB=0.405270	DNP=130.326966	DP=130.373502	DN=365118.351927	WD=2.007509	WN=0.000717
VBP=0.323661	VBN=0.086748	VB=0.399591	DNP=104.676954	DP=104.706973	DN=365118.351927	WD=2.224258	WN=0.000638
VBP=0.323661	VBN=0.092170	VB=0.394170	DNP=104.669967	DP=104.706973	DN=296156.441152	WD=2.209190	WN=0.000781
VBP=0.323661	VBN=0.097591	VB=0.388748	DNP=104.661353	DP=104.706973	DN=240219.745661	WD=2.194034	WN=0.000956
VBP=0.323661	VBN=0.103013	VB=0.383326	DNP=104.650736	DP=104.706973	DN=194848.121421	WD=2.178791	WN=0.001170
VBP=0.323661	VBN=0.108435	VB=0.377905	DNP=104.637650	DP=104.706973	DN=158046.085333	WD=2.163463	WN=0.001432
VBP=0.323661	VBN=0.113857	VB=0.372483	DNP=104.621521	DP=104.706973	DN=128195.052161	WD=2.148053	WN=0.001753
VBP=0.323661	VBN=0.119278	VB=0.367061	DNP=104.601642	DP=104.706973	DN=103982.147764	WD=2.132566	WN=0.002145
VBP=0.323661	VBN=0.124700	VB=0.361639	DNP=104.577146	DP=104.706973	DN=84342.467757	WD=2.117005	WN=0.002625
VBP=0.323661	VBN=0.130122	VB=0.356218	DNP=104.546961	DP=104.706973	DN=68412.242105	WD=2.101379	WN=0.003211
VBP=0.323661	VBN=0.135544	VB=0.350796	DNP=104.509771	DP=104.706973	DN=55490.845766	WD=2.085697	WN=0.003928
VBP=0.323661	VBN=0.140965	VB=0.345374	DNP=104.463958	DP=104.706973	DN=45009.984603	WD=2.069970	WN=0.004804
VBP=0.323661	VBN=0.146387	VB=0.339952	DNP=104.407532	DP=104.706973	DN=36508.701318	WD=2.054213	WN=0.005875
VBP=0.323661	VBN=0.151809	VB=0.334531	DNP=104.338051	DP=104.706973	DN=29613.102153	WD=2.038445	WN=0.007182
VBP=0.323661	VBN=0.157231	VB=0.329109	DNP=104.252518	DP=104.706973	DN=24019.912718	WD=2.022688	WN=0.008779
VBP=0.323661	VBN=0.162652	VB=0.323687	DNP=104.147261	DP=104.706973	DN=19483.139727	WD=2.006972	WN=0.010728

●N+N層の深さはできるだけ浅くする方が光電変換には有利である。

```
/******
```

```
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```

```
*****
```

```
#include <stdio.h>
```

```
#include <math.h>
```

```
double EG=1.11,kT=0.0259,Esi=648,NC=10400000,NV=28000000;
```

```
double VB,VBP,VBN,DP,DN,DNP,Vout,WD,WDD,WN;
```

```
double VBPP,VBNN,VBB;
```

```
int i,j;
```

```
char c;
```

```
FILE *fpBB;
```

```
void main(void){
```

```
fpBB=fopen("BB.txt","w");
```

```
/******
```

```
VBPP=(EG+kT*log(NV/NC))/2;
```

```
VBNN=(EG+kT*log(NC/NV))/2;
```

```
printf("VBPP=%f VBNN=%f\n",VBPP,VBNN);
```

```
fprintf(fpBB,"VBPP=%f VBNN=%f\n",VBPP,VBNN);
```

```
Vout=0.3;
```

```
VBB=0.2;
```

```
WDD=2;
```

```
printf("For { Vout=%f ; VB>VBB=%f ; WD>WDD=%f ; } \n",Vout,VBB,WDD);
```

```
fprintf(fpBB,"For { Vout=%f ; VB>VBB=%f ; WD>WDD=%f ; } \n",Vout,VBB,WDD);
```

```
i=1;
```

```
NEXT_i:
```

```
VBN=i*VBNN/100;
```

```
DN=NC*exp(-VBN/kT)-NV*exp((VBN-EG)/kT);
```

```
if (DN<100) goto JUMP_i;
```

```
j=1;
```

```

NEXT_j:

VBP=j*VBPP/100;

DP=NV*exp(-VBP/kT)-NC*exp((VBP-EG)/kT);

if (DP<100) goto JUMP_j;

if(DP>DN) goto JUMP_j;

VB=EG-Vout-VBN-VBP;

if(VB<VBB) goto JUMP_j;

DNP=DN*DP/(DN+DP);

WD=sqrt(2*Esi*VB/DNP);

WN=DP*WD/(DP+DN);

if(WD<WDD) goto JUMP_j;

if(DP>DN) goto JUMP_j;

printf("    %n VBP=%f VBN=%f VB=%f DNP=%f DP=%f DN=%f WD=%f WN=%f ",VBP,VBN,VB,DNP,DP,DN,WD,WN);

fprintf(fpBB, "%n VBP=%f VBN=%f VB=%f DNP=%f DP=%f DN=%f WD=%f WN=%f ",VBP,VBN,VB,DNP,DP,DN,WD,WN);

JUMP_j:j=j+1; if(j<100) goto NEXT_j;

JUMP_i:i=i+1; if(i<100) goto NEXT_i;

c=getchar( ); if(c=='!') printf("%n%n Good-bye !!");

fclose(fpBB); }

/***** End of C-code *****/

```