微电子器件物理　第二周作业

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作业内容：

1，阅读《半导体器件基础》第五章 done

2，使用 E5.1 和 E5.3 的程序，画出图 E5.1 和 E5.3 done

3、使用 E5.4 的程序，画图 3 种情况下的能带图 done

4、修改 E5.4 的程序，利用 subplot 函数，使之可以画出掺杂浓度、净电荷、电场、电势随着位置的关系图（类似图 5.9）done

5、修改 E5.4 的程序，使之可以画出施加不同偏压之后的能带图 done

6、课后作业：5.1、5.2、5.3、5.4

目录

Problem E5.1 E5.3

仿真图片分别 **图 1**，**图 2** 。

```
EG = 1.12;
kT = 0.0259;
ni = 1.0e10;

ND=logspace(14,17);
Vbi = EG/2 + kT.*log(ND./ni);

close
semilogx(ND, Vbi);grid
axis([1.0e14,1.0e17,0.75,1]);
xlabel('NA or ND (cm^-3)');
ylabel('Vbi (V)');
text(1e16,0.8,'Si 300k');
text(1e16, 0.78, 'p+/n and + /p diodes');
```

```
T = 300;
k = 8.617e-5;
e0 = 8.85e-14;
q = 1.602e-19;
KS = 11.8;
ni = 1e10;
EG = 1.12;

NB = logspace(14,17);
VA = [0.5, 0, -10];

Vbi = EG/2 + k*T .* log(NB./ni);
W = zeros(3, size(NB,2));
W = 1.0e4 * sqrt(2 * KS * e0 / q .* (Vbi - VA').*(1./NB));

close
loglog(NB, W, '-'); grid
axis([1.0e14, 1.0e17, 1.0e-1, 1.0e1])
xlabel('NA or ND (cm^-3)');
ylabel('W (um)');
set(gca, 'DefaultTextUnits', 'normalized')
text(.38, .26, 'VA=0.5V');
text(.38, .5, 'VA=0V');
text(.38, .75, 'VA=-10V');
text(.77, .82, 'Si 300K');
text(.77, .79, 'p+/n and n+/p');
set(gca, 'DefaultTextUnits', 'data') % gca Return a handle to the current axes
    object.
```

```
T = 300;
k = 8.617e-5;
e0 = 8.85e-14;
q = 1.602e-19;
KS = 11.8;
ni = 1e10;
EG = 1.12;

xleft = -3.5e-4;
```

```
xright = -xleft;
NA = input('Please enter p-side doping (cm^-3), NA = ');
ND = input('Please enter n-side doping (cm^-3), ND = ');
VA = input('Please enter VA (V), VA = ');
%NA = 1e18;
%ND = 1e16;

Vbi=k*T*log((NA*ND)/ni^2);
Vbi=Vbi-VA;
xN=sqrt(2*KS*e0/q*NA*Vbi/(ND*(NA+ND)));    % Depletion width n-side
xP=sqrt(2*KS*e0/q*ND*Vbi/(NA*(NA+ND)));    % Depletion width p-side
x = linspace(xleft, xright, 200);
% Vx1=(Vbi-q*ND.* (xN-x).^2/(2*KS*e0).*(x<=xN).*(x>=0));
Vx1=(Vbi-q*ND.*(xN-x).^2/(2*KS*e0).*(x<=xN)).*(x>=0);
Vx2=0.5*q*NA.*(xP+x).^2/(KS*e0).*( x>=-xP & x<0 );
Vx = Vx1 + Vx2;
VMAX = 3;
EF = Vx(1) + VMAX/2-k*T*log(NA/ni);


close

subplot(5,1,1);

str_title = sprintf('ND = %e, NA = %e Enegry Band', ND, NA);
title(str_title);

plot(x, -Vx+EG/2+VMAX/2); grid
axis([xleft, xright, 0, VMAX])
axis('off');hold on
plot ( x, -Vx-EG/2+VMAX/2);
plot(x, -Vx+VMAX/2, 'w:');
plot([xleft, xright], [EF, EF], 'w');
plot([0 0], [0.15, VMAX-0.5], 'w--');

text(xleft*1.08, (-Vx(1)+EG/2+VMAX/2-0.05),'Ec');
text(xright*1.02, (-Vx(200)+EG/2+VMAX/2-0.05), 'Ec');
text(xleft*1.08, (-Vx(1)-EG/2+VMAX/2-0.05),'Ev');
```

```
text(xright*1.02, (-Vx(200)-EG/2+VMAX/2-0.5), 'Ev');
text(xleft*1.08, (-Vx(1)+VMAX/2-0.05),'Ei');
text(xright*1.02, (EF-0.05), 'EF');
set(gca, 'DefaultTextUnits', 'normalized')
text(.18, 0, 'pside');
text(.47, .0, 'x=0');
text(.75, .0, 'nside');
set(gca, 'DefaultTextUnits', 'data') % gca Return a handle to the current axes
    object.
title(str_title);


subplot(5,1,2);

str_title = sprintf('ND = %e, NA = %e Distro of Impurities', ND, NA);
title(str_title);

hold on;

axis([xleft, xright, -20, 20]);
plot(x, -log10(NA*(x<0)));
plot(x, log10(ND*(x>=0)));
xlabel('x axis');
ylabel('ND-NA in log10');


subplot(5,1,3);
eps = 1e-16;
str_title = sprintf('ND = %e, NA = %e desity of charge', ND, NA);
title(str_title);
hold on;
axis(2*[10*(-xP), xN]);
mask_p = (x < 0) & (x >= -xP-eps);
mask_n = (x >= 0) & (x <= xN);
plot(x, -log10(q*NA*mask_p));
plot(x, log10(q*ND*mask_n+eps));

xlabel('x axis');
```

```
ylabel('\rho in log10');
```

```
subplot(5,1,4);

str_title = sprintf('ND = %e, NA = %e electric field', ND, NA);
title(str_title);
hold on;
axis(2*[(-xP), xN]);

plot(x, (-q*NA*mask_p/KS/e0.*(xP+x)));
plot(x, (-q*ND*mask_n/KS/e0.*(xN-x)));

xlabel('x axis');
ylabel('E');
```

```
subplot(5,1,5);

str_title = sprintf('ND = %e, NA = %e potential', ND, NA);
title(str_title);
hold on;
axis([(-xP), xN]);

plot(x, (q*NA*mask_p/2/KS/e0.*(xP+x).^2));
plot(x, (Vbi-q*ND*mask_n/KS/e0.*(xN).^2));

xlabel('x axis');
ylabel('E');
```

Problem E5.4

Problem 5.1

a) ✗ b) ✓ c) ✗ d) ✓ e) ✓ f) ✗ g) ✓ h) ✓ i) ✗ j) ✓

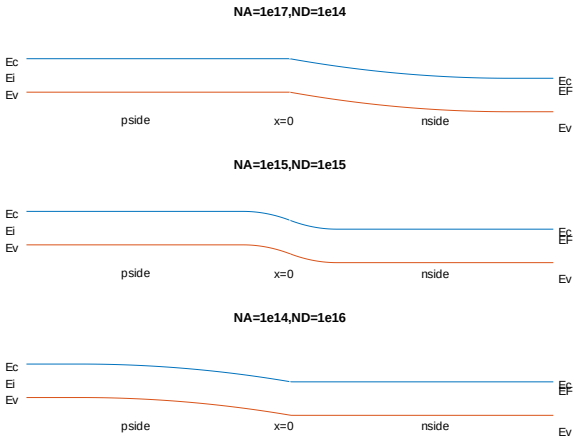

图 1: 题 1 图

Problem 5.2

SubProblem a

$$p = N_V \exp(\frac{E_i - E_F}{kT})$$

如 **图 3** 。

SubProblem b

$$E_F = E_V - 2kT = E_C - E_G/4$$

$$E_C + V_{bi}q = E_V + E_G$$

联立

$$V_{bi} = \frac{3}{4}E_G + 2kT$$

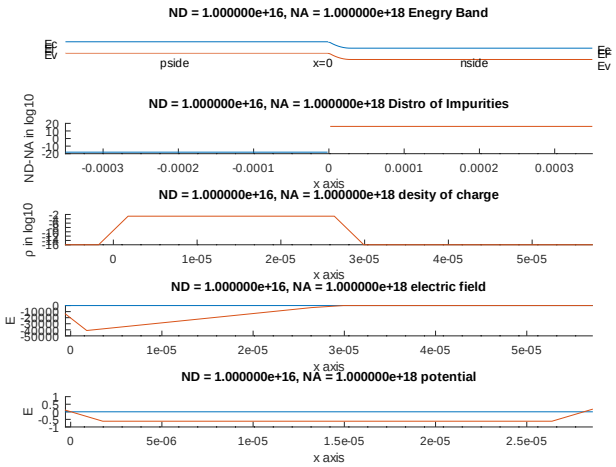

图 2: 题 2 图

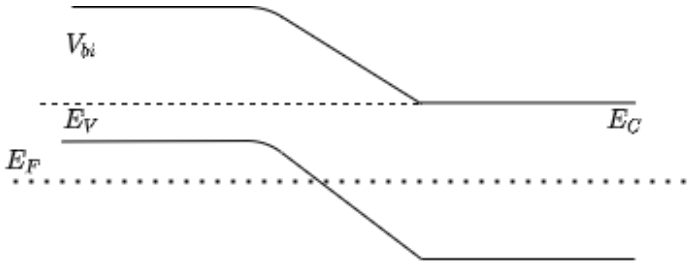

图 3: 5.2 能带

Problem 5.3

SubProblem a

如 **图 4** 。

SubProblem b

内建电势满足

$$V_{bi}q = E_{V1} - E_{V2}$$

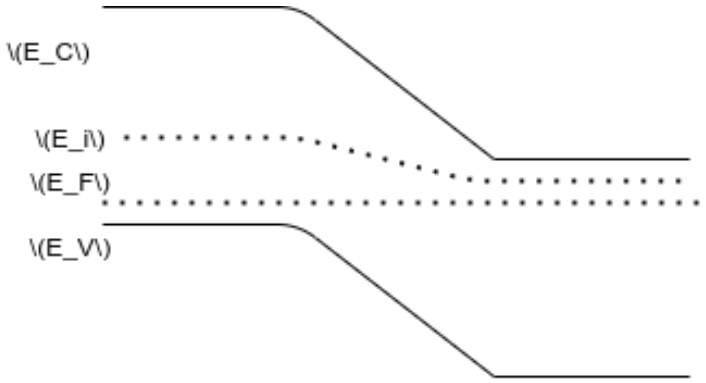

图 4: 5.3 能带

而

$$N_{A1} = p = N_V \exp(-\frac{E_i - E_{V1}}{kT})$$

$$N_{A2} = p = N_V \exp(-\frac{E_i - E_{V2}}{kT})$$

$$\frac{N_{A1}}{N_{A2}} = \exp(\frac{V_{bi}q}{kT})$$

那么

$$V_{bi} = \log(\frac{N_{A1}}{N_{A2}})\frac{kT}{q}$$

SubProblem c

如**图 5** 。

SubProblem d

耗尽近似对结区只考虑电离杂质，对远离结区部分认为其平衡，总电荷密度为 0 。

SubProblem e

静电变量表示为:

$$\rho = q(p - n + N_D - N_A)$$

如**图 6** 。

在远离结区的部分：$\rho = q \cdot p$

在结区：$\rho = q(p - N_A)$

不适用于耗尽近似，因为在结区没有发生两种载流子的耗尽。

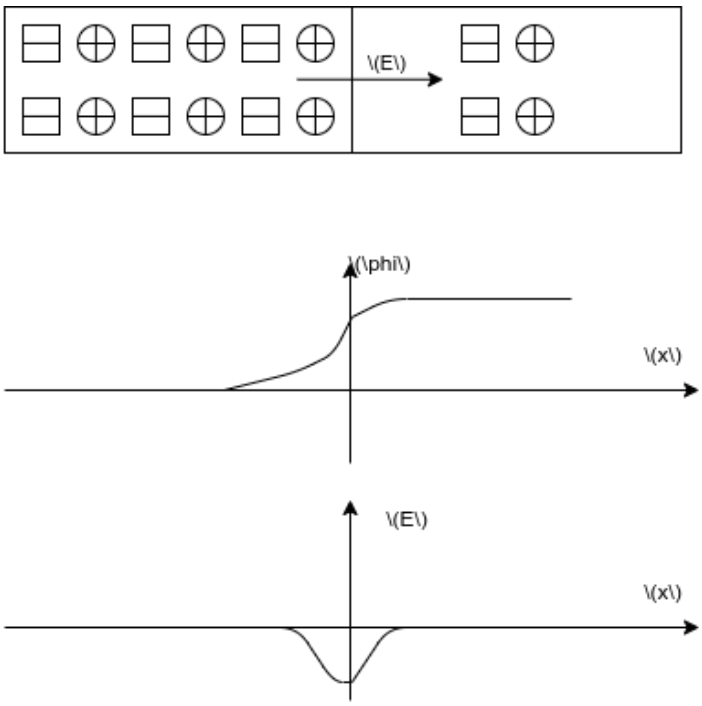

图 5: 5.3 电场、电势、电荷

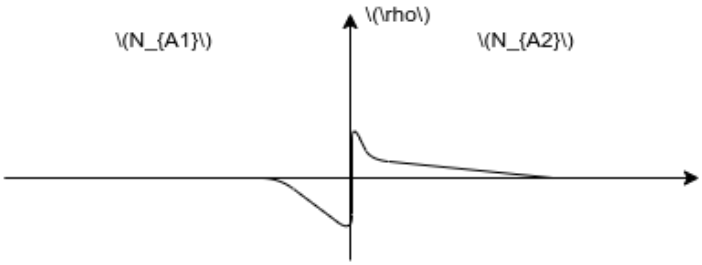

图 6: 5.3 静电变量

Problem 5.4

$$V_{bi} = \frac{kT}{q}\log(\frac{N_A N_D}{n_i^2}) = 0.61316V$$

$$x_p = \left[\frac{2K_S\epsilon_0}{1}\left(\frac{N_D}{N_A(N_A+N_D)}\right)\right] = 0.000073002cm$$

$$x_p = \left[\frac{2K_S\epsilon_0}{1}\left(\frac{N_A}{N_D(N_A+N_D)}\right)\right] = 0.000036501cm$$

$$W = x_n + x_p = \left[\frac{2K_S\epsilon_0}{1}\left(\frac{N_A+N_D}{N_A N_D}\right)\right]^{1/2} = 0.00010950cm$$

$$E(0) = -\frac{qN_D}{K_S\epsilon_0}(x_n) = 11198.88614V/cm$$

$$V(0) = -\frac{qN_A}{K_S\epsilon_0}\frac{1}{2}x_p^2 = 0.20439V$$