METAL SEMICONDUCTOR JUNCTION SCHOTTKY BARRIER

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Annotation: The Schottky barrier diode, formed by the metal-semiconductor junction, exhibits non-linear diode characteristics and offers rapid response due to unipolar carrier transport. In an ideal Schottky barrier, the height of the barrier is determined by the difference between the semiconductor’s conduction band and the metal’s Fermi level. This research provides insights into the behavior of the Schottky barrier diode, paving the way for applications in fast-switching electronics.

Keywords: schottky barrier diode, metal-semiconductor junction, unipolar carrier transport, band profile, Fermi level alignment, dipole region, conduction band, fast-switching electronics, semiconductor surface defects, ideal Schottky barrier.

The metal-semiconductor junction can result in a junction that has non-linear diode characteristics similar to those of the *p-n* diode except that for many applications it has a much faster response since carrier transport is unipolar. Such a junction is called a Schottky barrier diode.

The working of the Schottky diode depends upon how the metal-semiconductor junction behaves in response to external bias. Let us pursue the approximation we used for the *p-n* junction and examine the band profile of a metal and a semiconductor. A metal semiconductor structure is shown in figure 1.1a. In figure 1.1b and figure 1.1c the band profiles of a metal and a semiconductor are shown. Figure 1.1b shows that the band profile and Fermi level positions when the metal is away from the semiconductor. In figure 1.1c the metal and the semiconductor are in contact. The Fermi level E_{Fm} in the metal lies in the band, as shown. Also shown is the work function $e\varphi_m$. In the semiconductor, we show the vacuum level along with the position of the Fermi level E_{Fs} in the semiconductor, the electron affinity, and the work function.

We will assume an ideal surface for the semiconductor in the first calculation. Later we will examine the effect of surface defects. We will assume that $\varphi_m > \varphi_s$ so that the Fermi level in the metal is at a lower position than in the semiconductor. Table 5.2: Schottky barrier heights (in volts) for several metals on n-and p-type semiconductors. This condition leads to an n type Schottky barrier. When the junction between the two systems is formed, the Fermi levels should line up at the junction and remain flat in the absence of any current, as shown in figure 1.1c. At the junction, the vacuum energy levels of the metal side and semiconductor side must be the same. To ensure the continuity of the vacuum level and align the Fermi levels. Electrons move out from the semiconductor side to the metal side.

Schottky Metal	*n* Si	*p* Si	*n* GaAs
Aluminum, Al	0.7	0.8	
Titanium, Ti	0.5	0.61	
Tungsten, W	0.67		
Gold, Au	0.79	0.25	0.9
Silver, Ag			0.88
Platinum, Pt			0.86
PtSi	0.85	0.2	
$NiSi_2$	0.7	0.45	

As electrons move to the metal side, they leave behind positively charged fixed dopants, and a dipole region is produced in the same way as for the *p-n* diode. In the ideal Schottky barrier with no band gap defect levels, the height of the barrier at the semiconductor-metal junction (figure 1.1c),

is defined as the difference between the semiconductor conduction band at the junction and the metal Fermi level. This barrier is given by (see figure 1.1c)

$$e\varphi_b = e\varphi_m - e\chi_s \quad (1)$$

The electrons coming from the semiconductor into the metal face a barrier denoted by eV_{bi} as shown in figure 1.1c. The potential eV_{bi} is called the built-in potential of the junction and is given by

$$eV_{bi} = -(e\varphi_m - e\varphi_s) \quad (2)$$

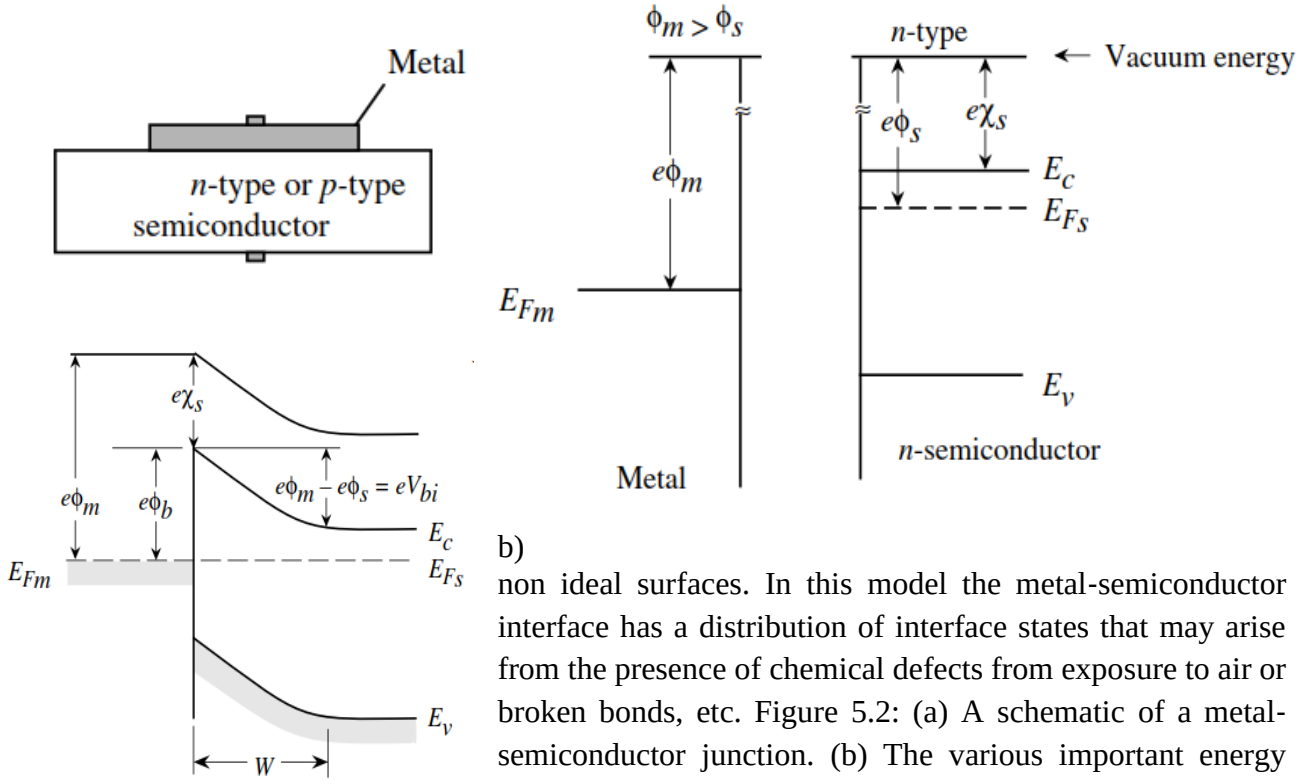
It is possible to have a barrier for hole transport if $\varphi_m < \varphi_s$. In figure 1. we show the case of a metal-p-type semiconductor junction where we choose a metal so that $\varphi_m < \varphi_s$. In this case, at equilibrium the electrons are injected from the metal to the semiconductor, causing a negative charge on the semiconductor side.

The bands are bent once again and a barrier is created for hole transport. The height of the barrier seen by the holes in the semiconductor is

$$eV_{bi} = e\varphi_s - e\varphi_m \quad (3)$$

The Schottky barrier height for n-or p-type semiconductors depends upon the metal and the semiconductor properties. This is true for an ideal case.

It is found experimentally that the Schottky barrier height is often independent of the metal employed, as can be seen from table 5.2. This can be understood qualitatively in terms of a model based upon



b)

non ideal surfaces. In this model the metal-semiconductor interface has a distribution of interface states that may arise from the presence of chemical defects from exposure to air or broken bonds, etc. Figure 5.2: (a) A schematic of a metal-semiconductor junction. (b) The various important energy levels in the metal and the semiconductor with respect to the vacuum level. (c) The junction potential produced when the metal and semiconductor are brought together. Due to the built-in potential at the junction, a depletion region of width W is created. We have seen in chapter 3 that defects can create bandgap states in a semiconductor. Surface defects can create $\sim 10^{13} sm^{-2}$defects if there is 1 in 10 defects at the surface. Surface defects lead to a distribution of electronic levels in the bandgap at the interface, as shown in figure 5.4. The distribution may be characterized by a neutral level φ_0 having the property that states below it are neutral if filled

and above it are neutral if empty. If the density of bandgap states near φ_0 is very large, then addition or depletion of electrons to the semiconductor can not alter the Fermi level position at the surface without large changes in surface charges (beyond the numbers demanded by charge neutrality considerations). Thus, the Fermi level is said to be pinned. In this case, as shown in figure 5.4, the Schottky barrier height is and is almost independent of the metal used.

$$e\varphi_b = E_g - e\phi_0 \qquad e\varphi_0 \tag{4}$$

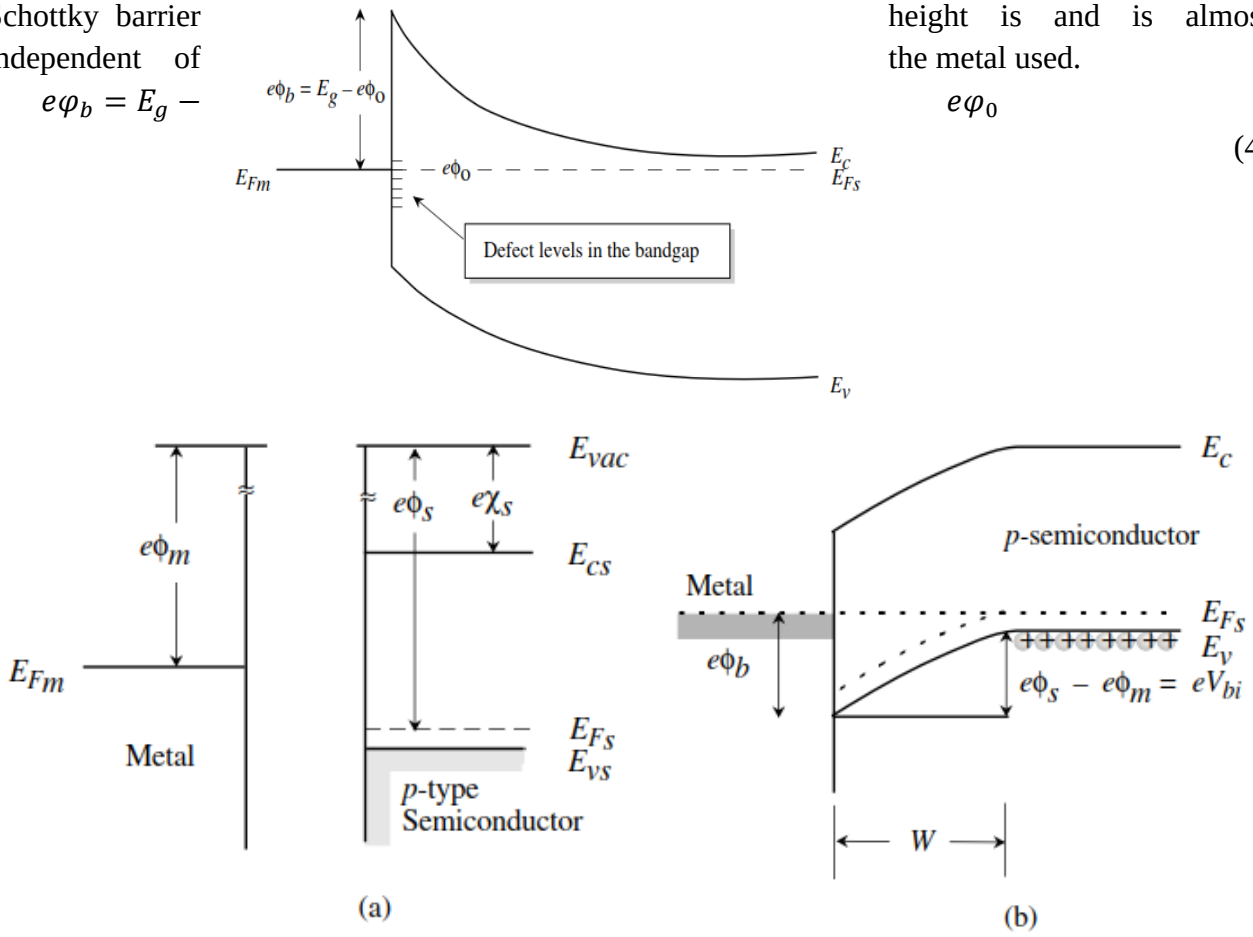


Figure 5.3: A schematic of the ideal p-type Schottky barrier formation. (a) The positions of the energy levels in the metal and the semiconductor; (b) the junction potential and the depletion width. The model discussed above provides a qualitative understanding of the Schottky barrier heights. However, the detailed mechanism of the interface state formation and Fermi level pinning is quite complex. In table 5.2 we show Schottky barrier heights for some common metal-semiconductor combinations. In some materials such as GaN and AlGaN,the surface retains its ideal behavior and the Schottky barrier is indeed controlled by the metal work function. Figure 5.4: Interface states at a real metal-semiconductor interface. A neutral level φ_0 is defined so that the interface states above φ_0 are neutral if they are empty and those below φ_0.

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КВАНТ ЎРАЛИ ГЕТЕРОСТРУКТУРАЛАРДА ИККИ ЎЛЧОВЛИ КОМБИНАЦИЯЛАНГАН ҲОЛАТЛАР ЗИЧЛИГИНИНГ ФОТОННИНГ ЮТУВЧИ ЭНЕРГИЯСИГА БОҒЛИҚЛИГИ

проф. Эркабоев У.И., таянч докторант Сайидов Н.А., талаба Ғайратов С.И.

Квант ўралари асосидаги аниқ тўғрисоҳали гетероструктуралар учун квантловчи магнит майдонида икки ўлчовли комбинацияланган ҳолатлар зичлигининг ҳароратга боғлиқлигини кўриб чиқамиз. [1] илмий-тадқиқот ишида, қалинлиги 14 нм, тўсиқ қатламларида озгина (3%) алюмний аралашган, GaAs/AlGaAs квант ўрали, юқори сифатли гетероструктуралар тадқиқ қилинган. Ушбу гетероструктуралар 4К ҳароратда ўрганилган.