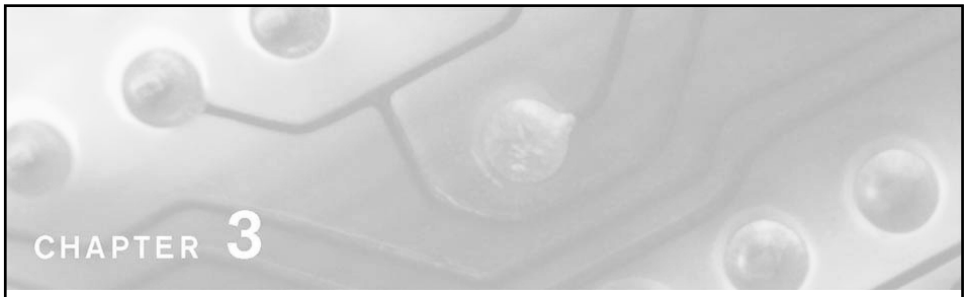
ECE321 Electronics I
Fall 2006

Professor James E. Morris

Lecture 7

17th October, 2006



Diodes

3.7 Diode Physics

(3.8 Other Diode Types)

3.9 SPICE

← Completely different type of material (not circuits)

Also: BJT device physics next lecture

2

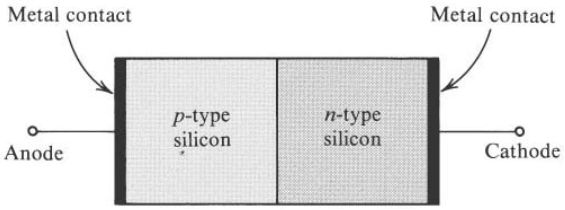


Figure 3.39 Simplified physical structure of the junction diode. (Actual geometries are given in Appendix A.)

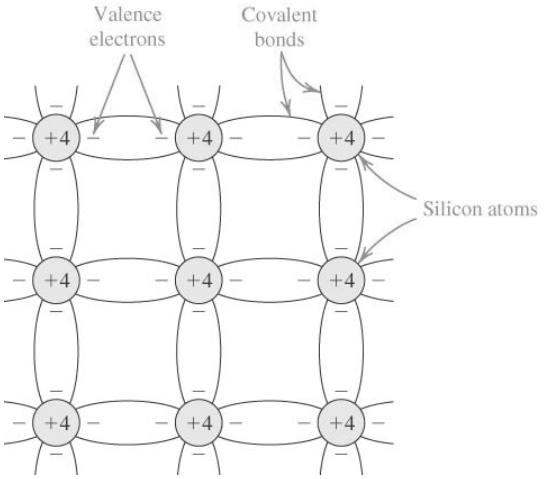


Figure 3.40 Two-dimensional representation of the silicon crystal. The circles represent the inner core of silicon atoms, with +4 indicating its positive charge of +4q, which is neutralized by the charge of the four valence electrons. Observe how the covalent bonds are formed by sharing of the valence electrons. At 0 K, all bonds are intact and no free electrons are available for current conduction.

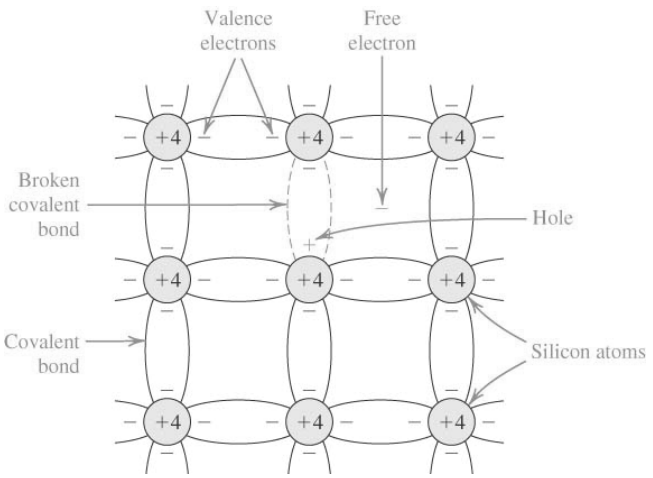


Figure 3.41 At room temperature, some of the covalent bonds are broken by thermal ionization. Each broken bond gives rise to a free electron and a hole, both of which become available for current conduction.

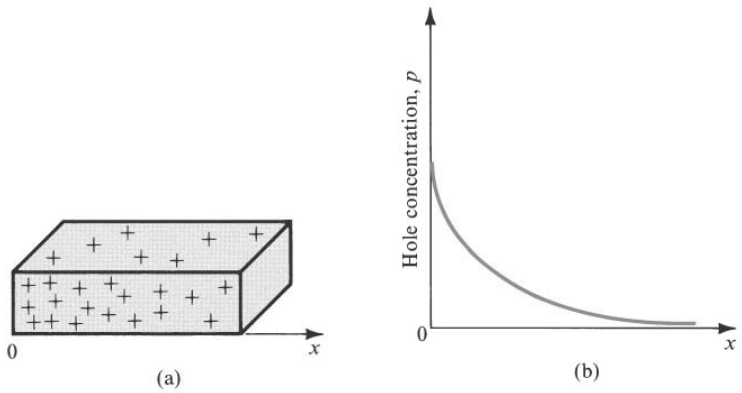


Figure 3.42 A bar of intrinsic silicon **(a)** in which the hole concentration profile shown in **(b)** has been created along the *x*-axis by some unspecified mechanism.

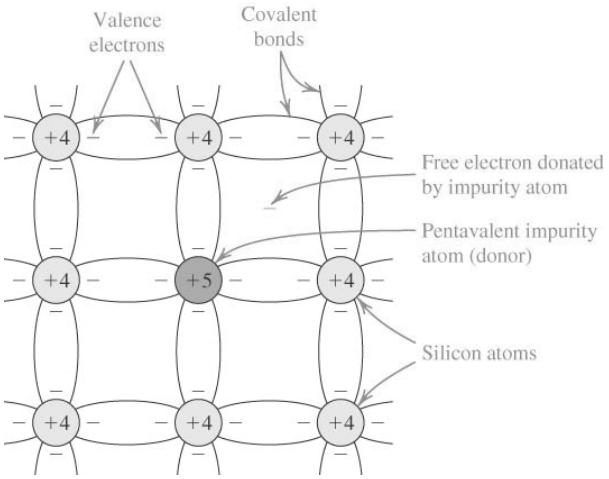


Figure 3.43 A silicon crystal doped by a pentavalent element. Each dopant atom donates a free electron and is thus called a donor. The doped semiconductor becomes *n* type.

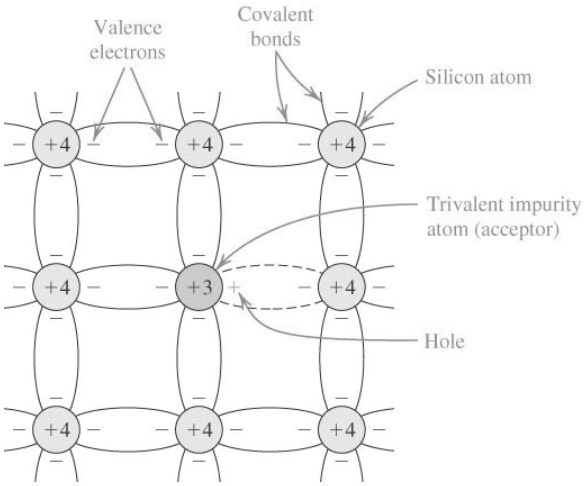


Figure 3.44 A silicon crystal doped with a trivalent impurity. Each dopant atom gives rise to a hole, and the semiconductor becomes *p* type.

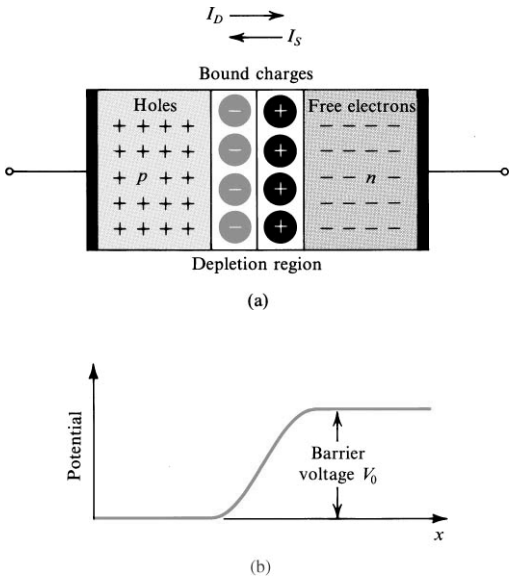


Figure 3.45 **(a)** The *pn* junction with no applied voltage (open-circuited terminals). **(b)** The potential distribution along an axis perpendicular to the junction.

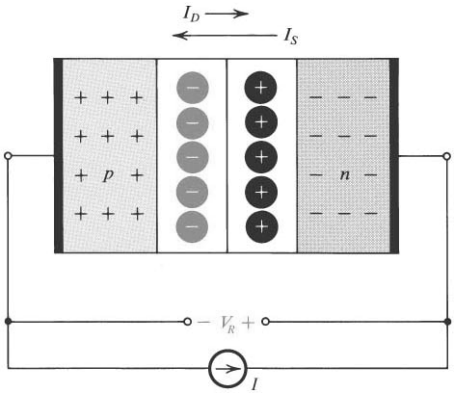


Figure 3.46 The *pn* junction excited by a constant-current source I in the reverse direction. To avoid breakdown, I is kept smaller than I_S. Note that the depletion layer widens and the barrier voltage increases by V_R volts, which appears between the terminals as a reverse voltage.

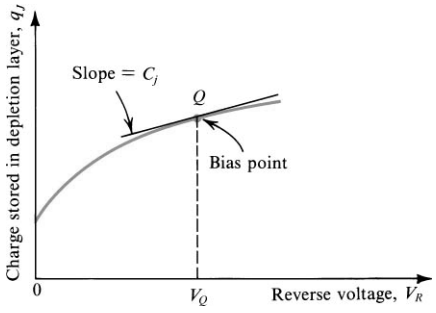


Figure 3.47 The charge stored on either side of the depletion layer as a function of the reverse voltage V_R.

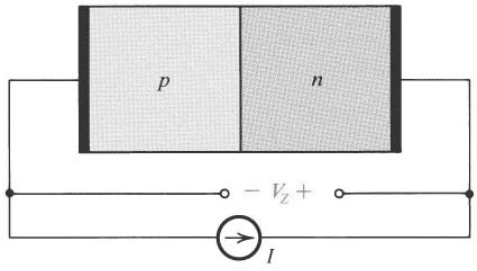


Figure 3.48 The *pn* junction excited by a reverse-current source I, where $I > I_s$. The junction breaks down, and a voltage V_Z, with the polarity indicated, develops across the junction.

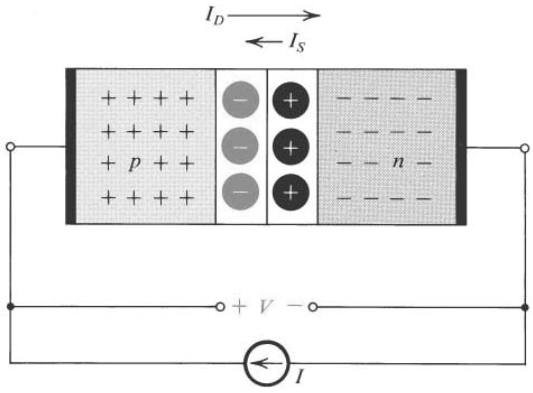


Figure 3.49 The *pn* junction excited by a constant-current source supplying a current *I* in the forward direction. The depletion layer narrows and the barrier voltage decreases by *V* volts, which appears as an external voltage in the forward direction.

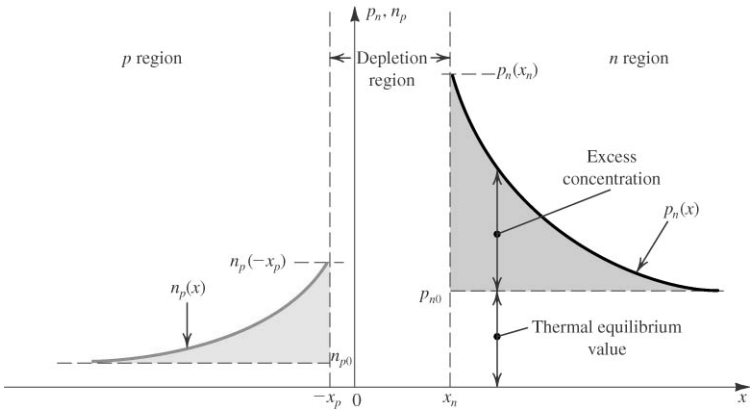
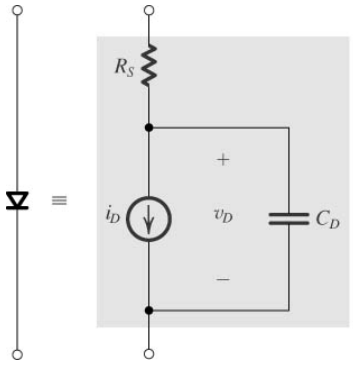


Figure 3.50 Minority-carrier distribution in a forward-biased *pn* junction. It is assumed that the *p* region is more heavily doped than the *n* region; $N_A @ N_D$.



$$i_D = I_S\left(e^{v_D/nV_T} - 1\right)$$

$$C_D = C_d + C_j = \frac{\tau_T}{V_T} I_S\, e^{v_D/nV_T} + C_{j0}\Big/\left(1 - \frac{v_D}{V_0}\right)^m$$

Figure 3.51 The SPICE diode model.

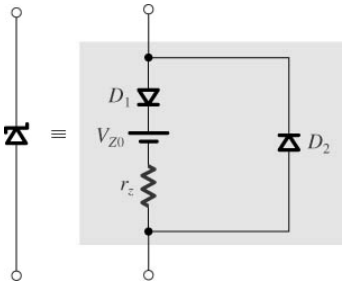


Figure 3.52 Equivalent-circuit model used to simulate the zener diode in SPICE. Diode D_1 is ideal and can be approximated in SPICE by using a very small value for n (say $n = 0.01$).

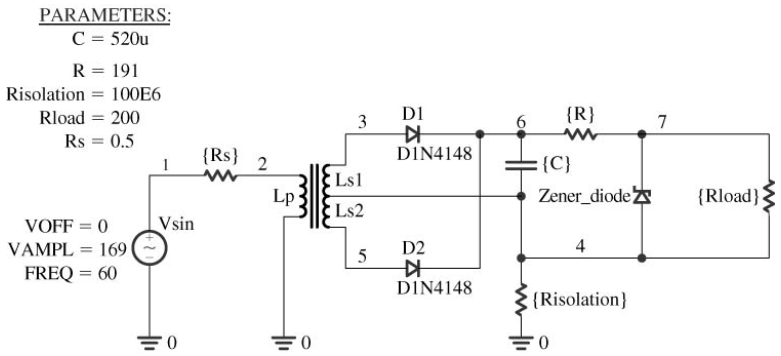


Figure 3.53 Capture schematic of the 5-V dc power supply in Example 3.10.

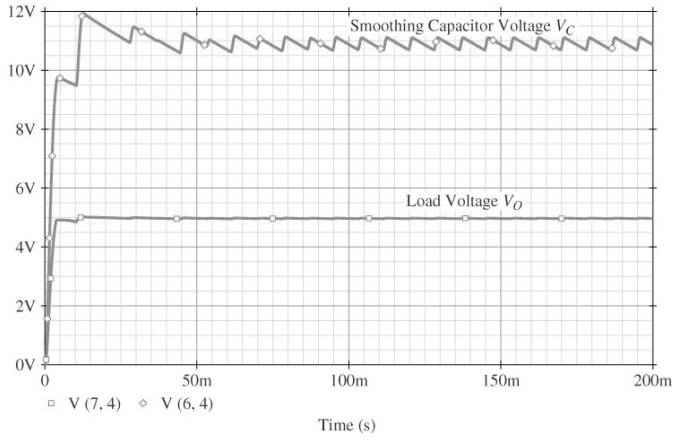


Figure 3.54 The voltage v_C across the smoothing capacitor C and the voltage v_O across the load resistor R_{load} = 200 Ω in the 5-V power supply of Example 3.10.

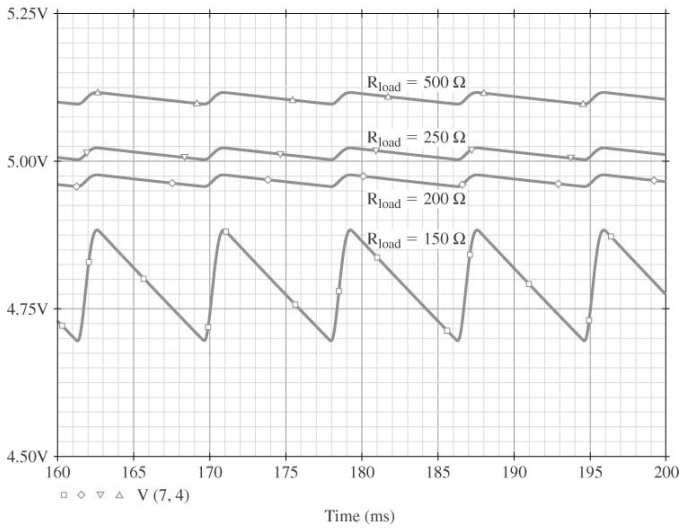


Figure 3.55 The output-voltage waveform from the 5-V power supply (in Example 3.10) for various load resistances: R_{load} = 500 Ω, 250 Ω, 200 Ω, and 150 Ω. The voltage regulation is lost at a load resistance of 150 Ω.

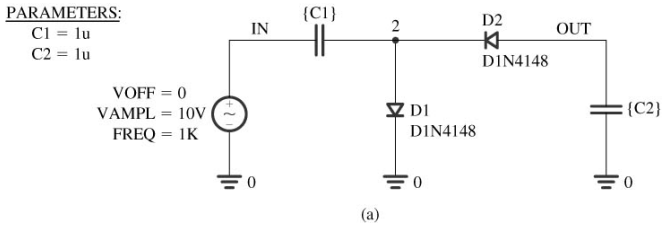


Figure E3.35 (a) Capture schematic of the voltage-doubler circuit (in Exercise 3.35).

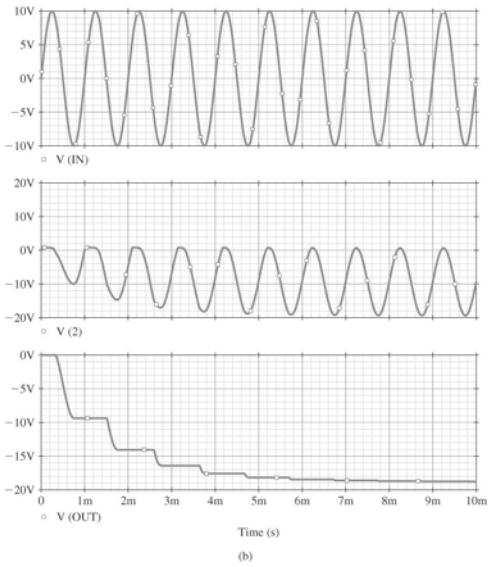


Figure E3.35 *(Continued)* **(b)** Various voltage waveforms in the voltage-doubler circuit. The top graph displays the input sine-wave voltage signal, the middle graph displays the voltage across diode D_1, and the bottom graph displays the voltage that appears at the output.