Semiconductor Device Theory:
Operation of a Schottky Diode –Theoretical Exercise

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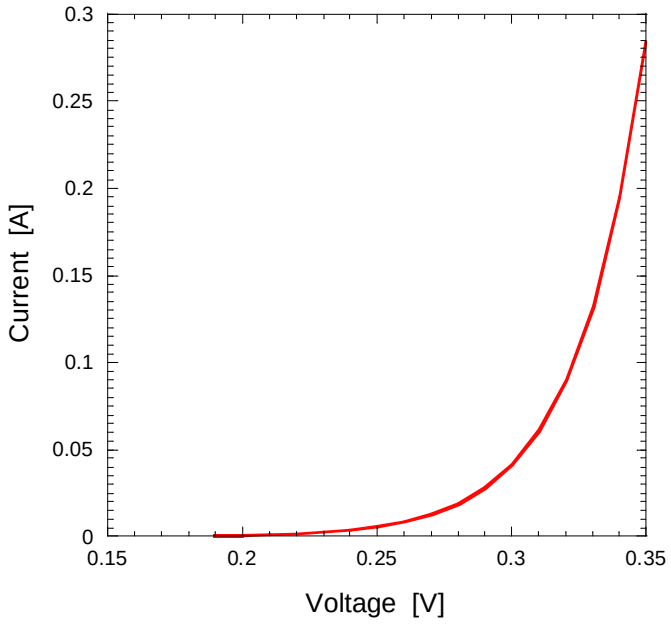
1. Explain qualitatively thermionic emission theory for describing current flow in Schottky barrier diodes. No actual derivations are needed.

   (a) On the graph provided below, sketch the magnitude of the current for the case when the Schottky barrier height is 25 meV lower.

   (b) How does the image force lowering effect affect the barrier height under forward and reverse bias conditions? Provide sketches of the energy band diagram under forward and reverse bias conditions that support your answers.



2. Compare the value of the saturation current densities for Schottky barrier (J_{SS}) with the saturation current density for a p^+n-junction (J_S). Show that

$$\frac{J_{SS}}{J_S} \approx (2\pi)^{-1/2} \frac{N_D}{N_C} \sqrt{\frac{\tau_{pl}}{\tau_p}} \frac{m_n}{m_p} \exp\left(\frac{qE_g - \Phi_B}{k_B T}\right)$$

   Where τ_{pl} is the hole lifetime in the n-type region, τ_p is the hole momentum relaxation time, E_g is the energy in the pn-junction, Φ_B is the Schottky barrier height, N_D is the donor density, and N_C is the effective density of states in the conduction band.

3. The measured capacitance of the reversed-biased silicon Schottky barrier diode is given by:

$$\frac{1}{C^2} = \frac{1}{C_0^2} - kV$$

where C_0=1 pF and k=2 $pF^{-2}V^{-1}$. The diode is uniformly doped. The dielectric permittivity $\varepsilon_s=1.05\times10^{-10}$ F/m. Device area is 10^{-4} cm^2. The effective density of states in the conduction band is $N_C=2.8\times10^{19}$ cm^{-3}. Find the Schottky barrier height.

4. A Schottky diode and a p^+n diode are connected as shown in the figures below. The values of the device parameters are:

Temperature	T = 300 K
Richardson constant	A*=5 $A/cm^2/K^2$
Schottky barrier height	Φ_B=0.8 eV
Ideality factor for both diodes	1
Cross-section of both diodes	$S=10^{-2}$ cm^2
Diffusion coefficient of holes	D_p= 9 cm^2/s
Length of the n-section	X_n= 3μm
Doping of the n section	$N_D=10^{15}$ cm^{-3}
Intrinsic carrier concentration	$n_i=10^{10}$ cm^{-3}
Hole lifetime in the n section	$\tau=10^{-6}$ s

Assume ideal diode equations. The applied voltage is 0.8 V. Find the electric current and voltage drop across the diodes.