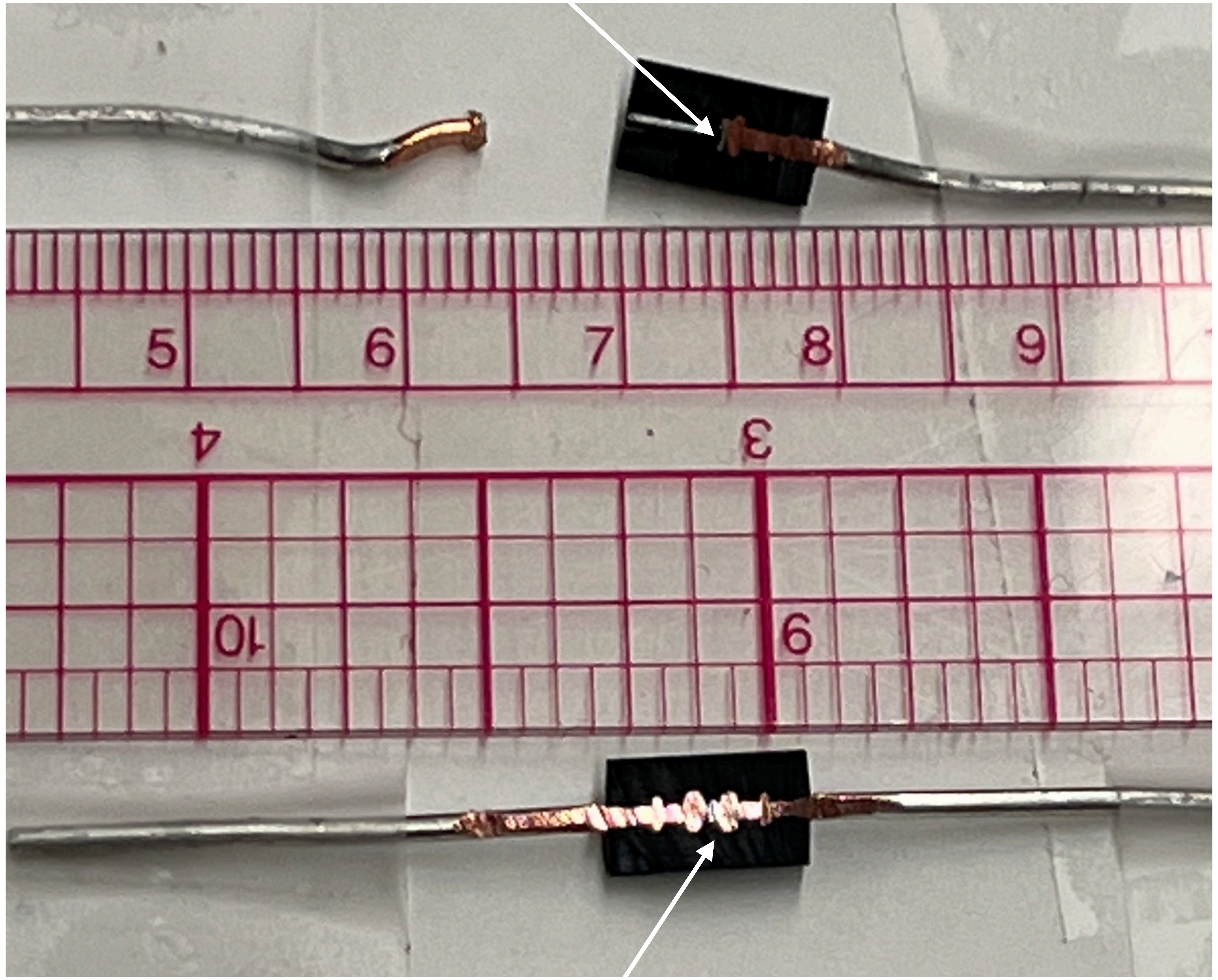
Schottky Diode I-V & C-V Characteristics

AP 4018
Columbia University

Objectives: Schottky Diode Experiments

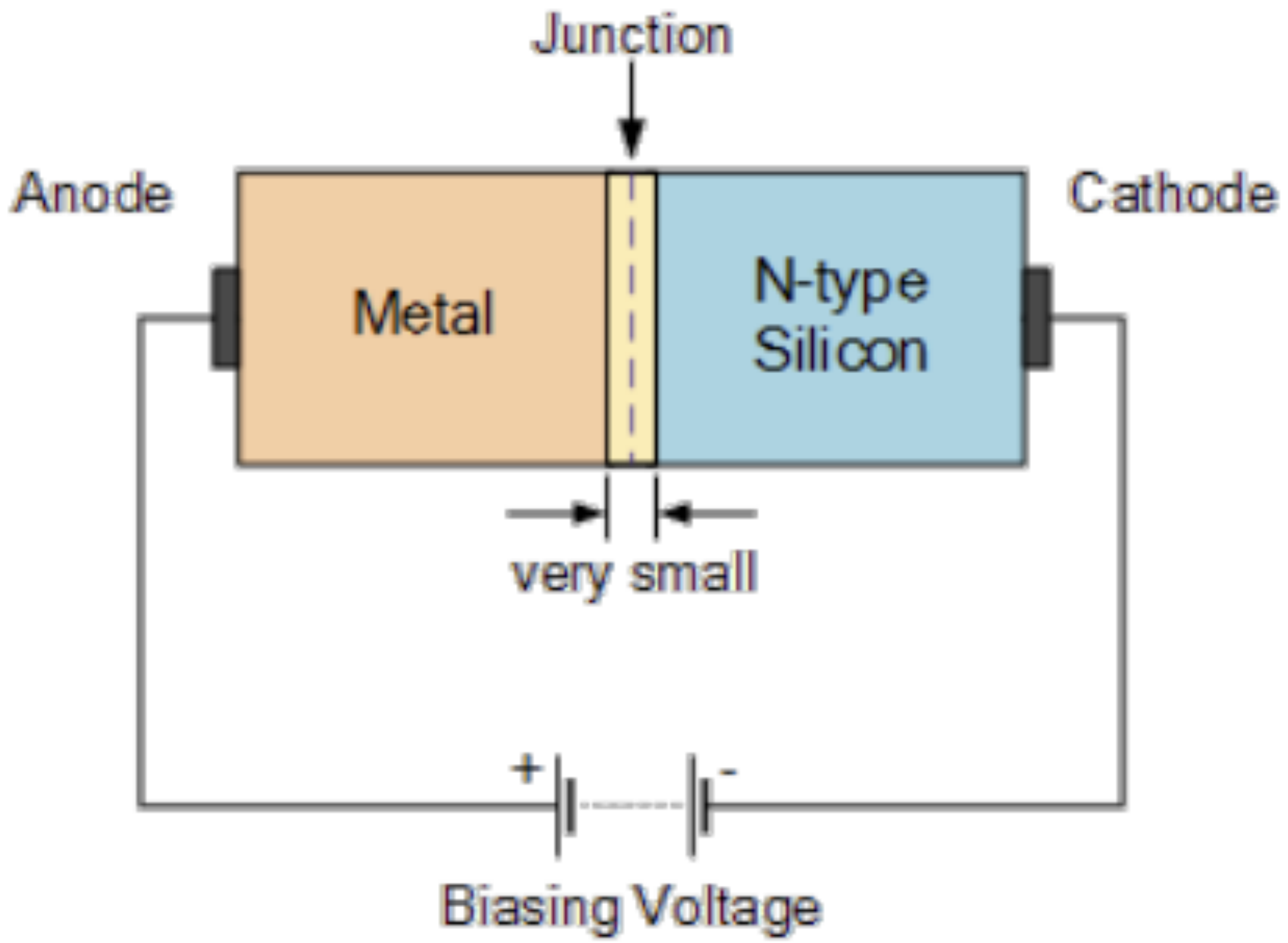
- Understand the metal-semiconductor junction
- Measure the current-voltage (I-V) characteristics
- Measure the diode capacitance as a function of reverse bias
- Compute estimates of the semi-conductor doping concentration
- Use a Schottky Diode in a circuit

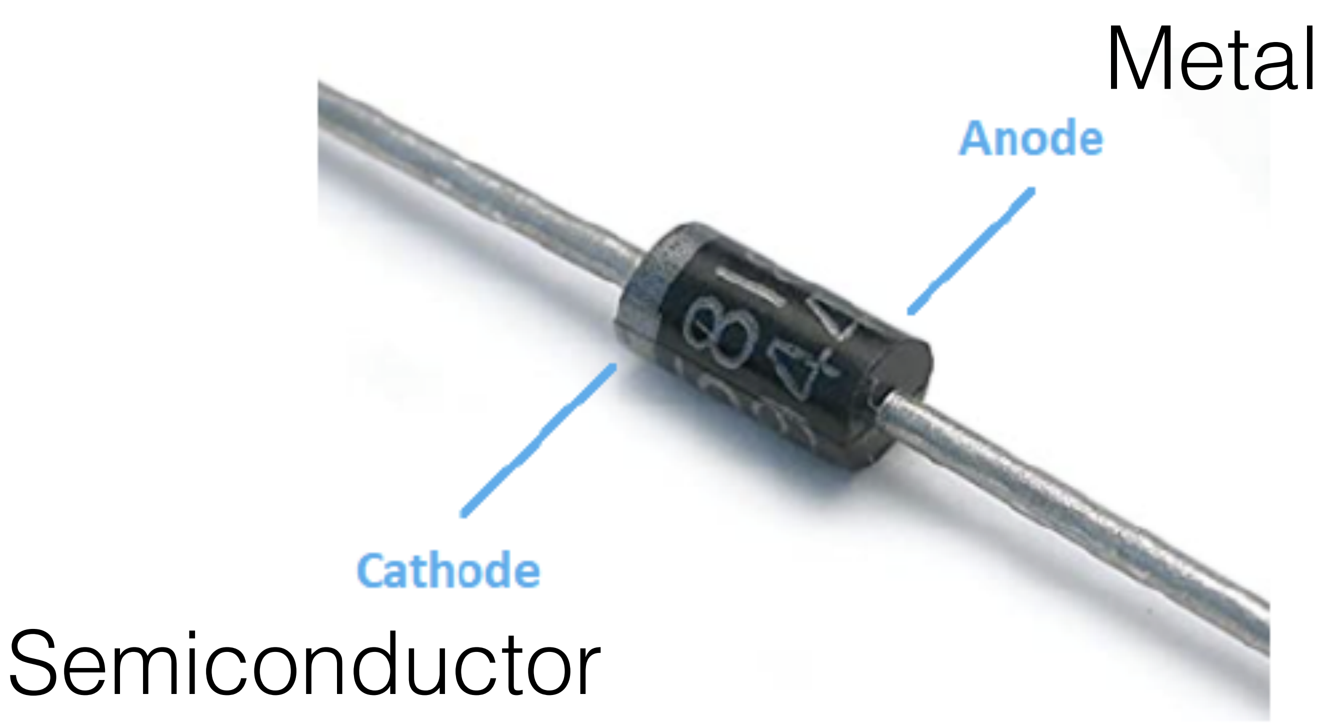
Diode: n-Type/Cr



Diode: n-Type/Cr

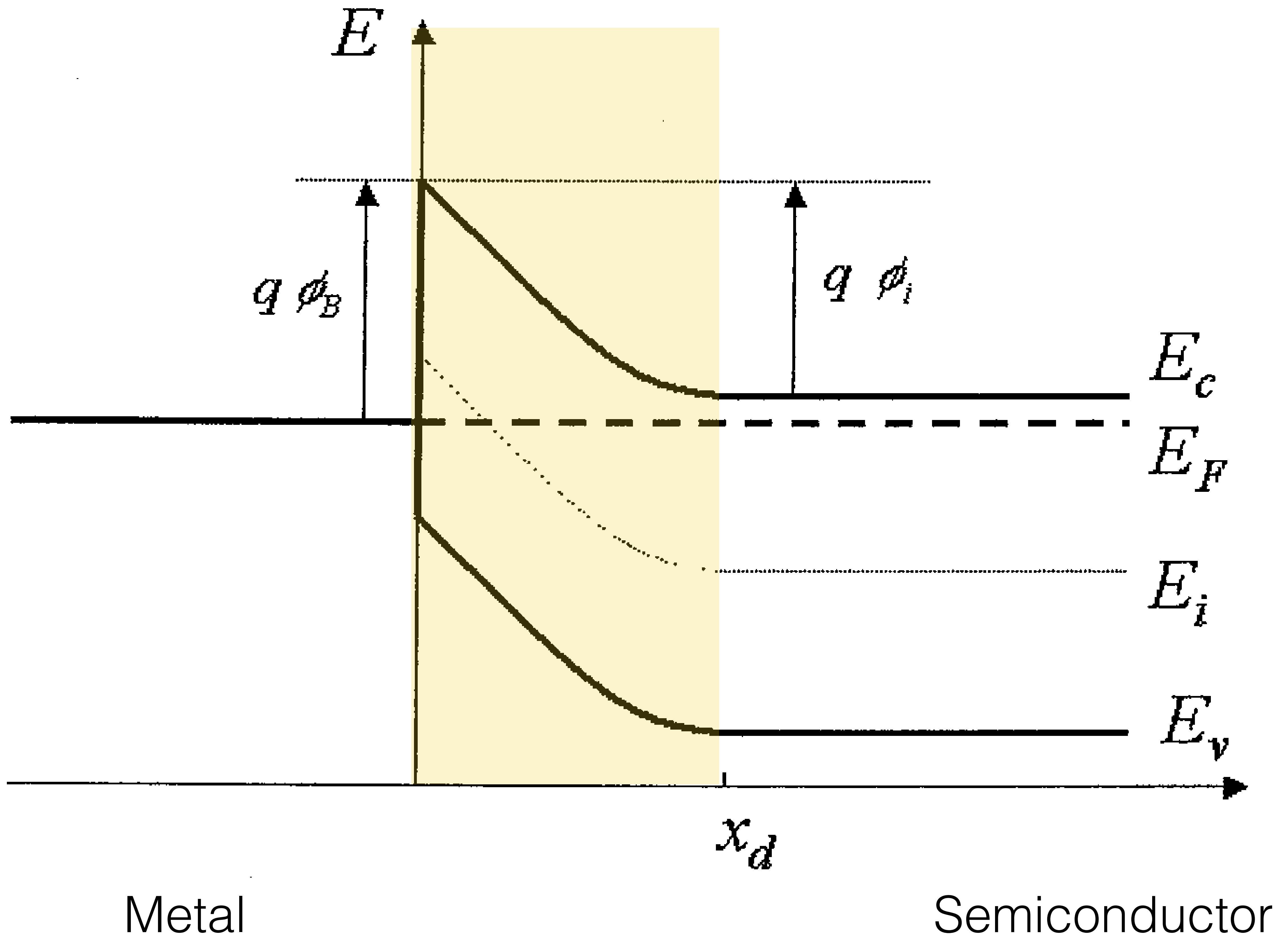
What is a Schottky Diode?





- Metal-Semiconductor junction creates a “built-in” potential barrier at a very small depletion layer.
- When a positive voltage is applied to the metal, more electrons can flow from the semiconductor to the metal; *current increase*.
- When a negative voltage is applied to the metal, the depletion layer grows, but the barrier from the metal to semiconductor is unchanged; *current is constant*.

Energy Band Diagram of Schottky Diode



x_d = depletion width

	Ag	Al	Au	Cr	Ni	Pt	W
Φ_M (in vacuum)	4.3	4.25	4.8	4.5	4.5	5.3	4.6
n-Ge	0.54	0.48	0.59		0.49		0.48
p-Ge	0.5		0.3				
n-Si	0.78	0.72	0.8	0.61	0.61	0.9	0.67
p-Si	0.54	0.58	0.34	0.5	0.51		0.45
n-GaAs	0.88	0.8	0.9			0.84	0.8
p-GaAs	0.63		0.42				

(for the 1N5821: ϕ_B = 0.61 V)

Forward and Reverse Bias

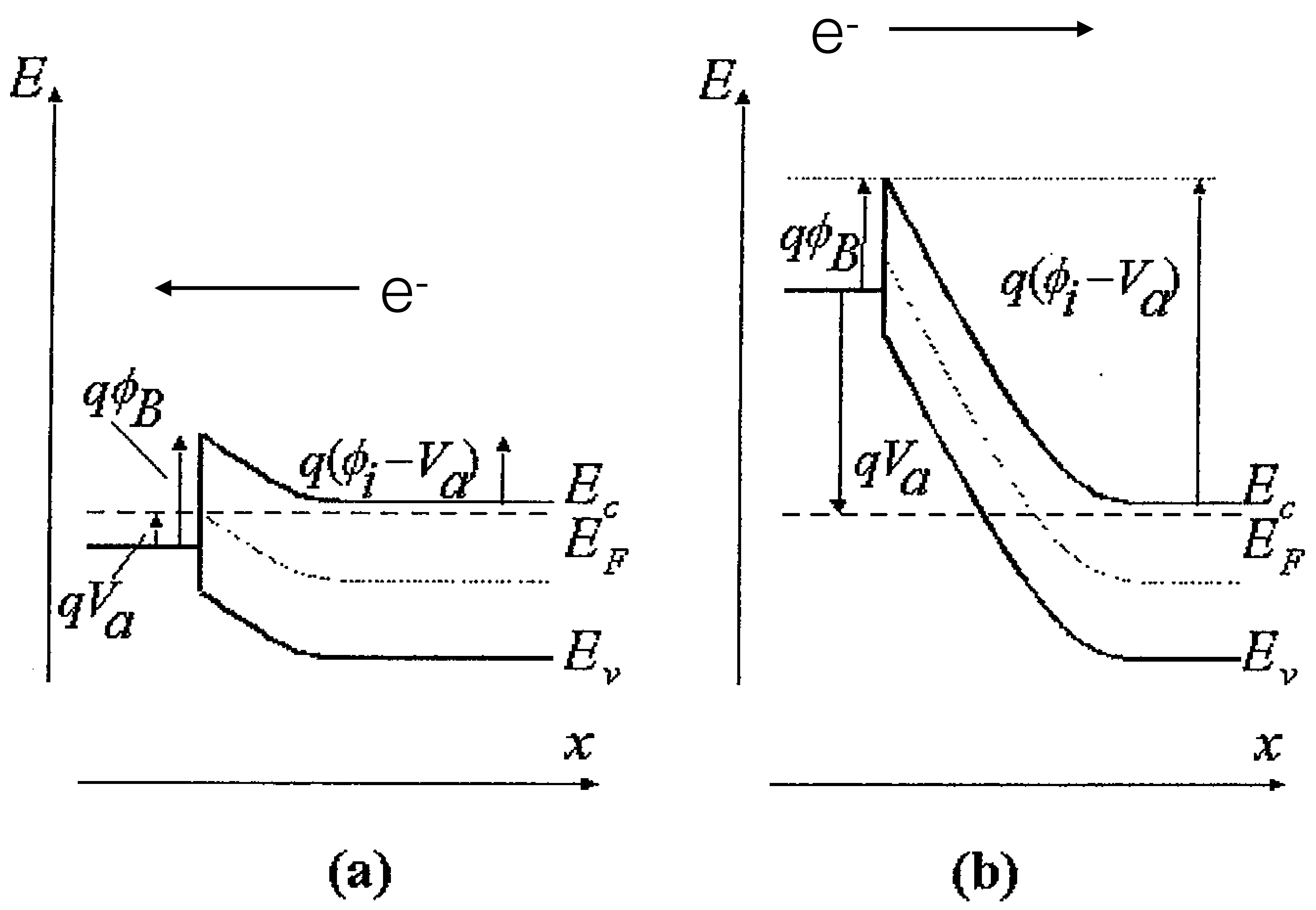
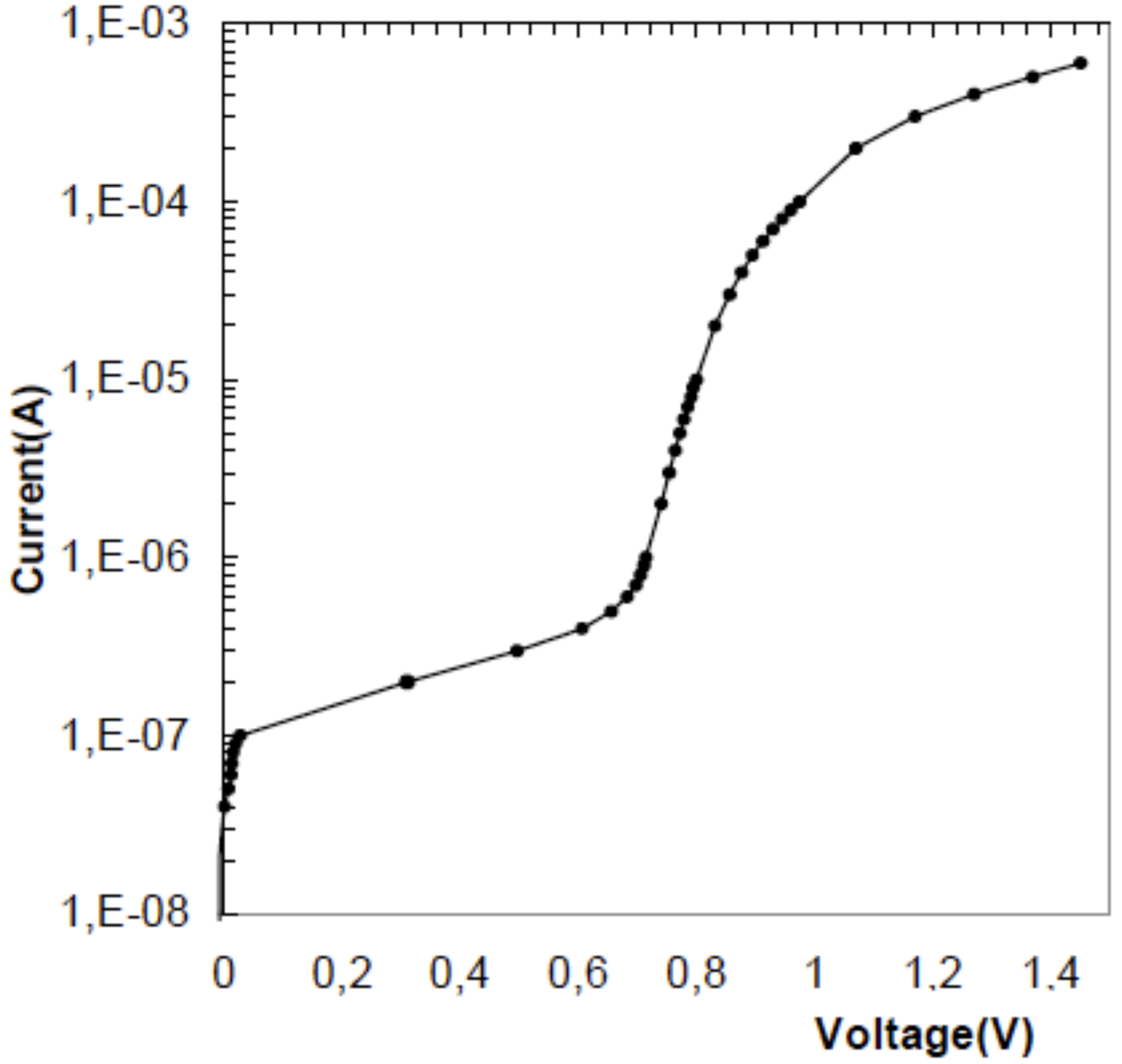


Figure 4 : Energy band diagram of a metal-semiconductor junction under (a) forward and (b) reverse bias

Key Measurements

- Current-Voltage (I-V) characteristics
- Capacitance-Voltage (C-V) characteristics



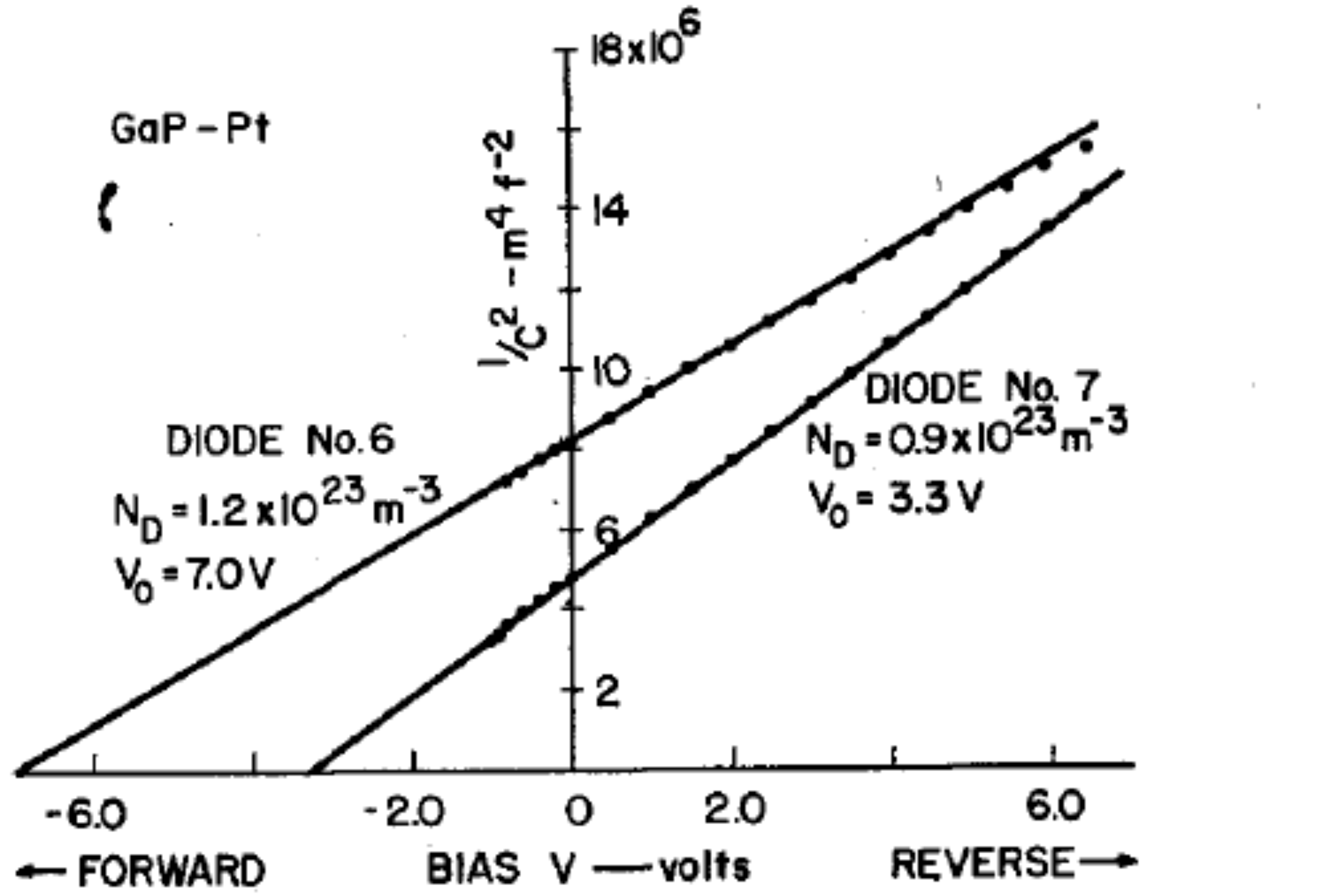


FIG. 1. $1/C^2$ vs V plots for GaP–Pt diodes prepared in the oil-diffusion vacuum system. Values of N_D for each curve have been calculated from the usual formula relating N_D to the slope of the $1/C^2$ plot: $N_D = (2/e\epsilon_s)/[d(1/C^2)/dV]$.

$$I = I_S\left[\exp\left(\frac{qV_B}{kT}\right) - 1\right] \quad I_S = AA^*T^2\exp(-q\phi_B/kT)$$

$$\frac{1}{C_m^2} = \frac{2(V_{bi} - V_i)}{q\varepsilon_s\varepsilon_o N_D A^2}$$

Surface states, barrier heights, and Schottky diodes have a rich scientific history in solid-state physics. See:

- A. M. Cowley and S. M. Sze, "Surface States and Barrier Height of Metal-Semiconductor Systems," Journal of Applied Physics 36, 3212 (1965); https://doi.org/10.1063/1.1702952
- A. M. Cowley, "Depletion Capacitance and Diffusion Potential of Gallium Phosphide Schottky-Barrier Diodes," Journal of Applied Physics 37, 3024 (1966); https://doi.org/10.1063/1.1703157

IN5821 Schottky Diode

1N5820, 1N5821, 1N5822

1N5820 and 1N5822 are Preferred Devices

Axial Lead Rectifiers

This series employs the Schottky Barrier principle in a large area metal−to−silicon power diode. State−of−the−art geometry features chrome barrier metal, epitaxial construction with oxide passivation and metal overlap contact. Ideally suited for use as rectifiers in low−voltage, high−frequency inverters, free wheeling diodes, and polarity protection diodes.

Features

- Extremely Low V_F
- Low Power Loss/High Efficiency
- Low Stored Charge, Majority Carrier Conduction
- Shipped in plastic bags, 500 per bag
- Available in Tape and Reel, 1500 per reel, by adding a “RL” suffix to the part number
- Pb−Free Packages are Available*

Mechanical Characteristics:

- Case: Epoxy, Molded
- Weight: 1.1 Gram (Approximately)
- Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable
- Lead Temperature for Soldering Purposes: 260°C Max. for 10 Seconds
- Polarity: Cathode indicated by Polarity Band

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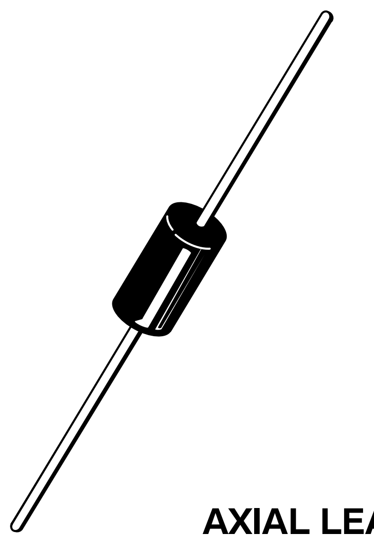
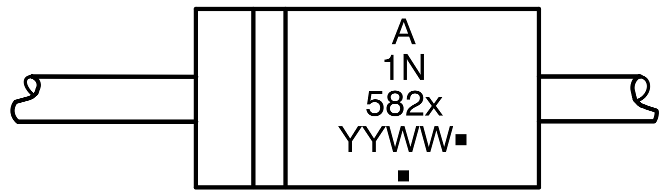
http://onsemi.com

SCHOTTKY BARRIER RECTIFIERS
3.0 AMPERES
20, 30, 40 VOLTS



AXIAL LEAD
CASE 267−05
(DO−201AD)
STYLE 1

MARKING DIAGRAM



A	= Assembly Location
1N582x	= Device Code
x	= 0, 1, or 2
YY	= Year
WW	= Work Week
▪	= Pb−Free Package

(Note: Microdot may be in either location)

ORDERING INFORMATION

See detailed ordering and shipping information on page 3 of this data sheet.

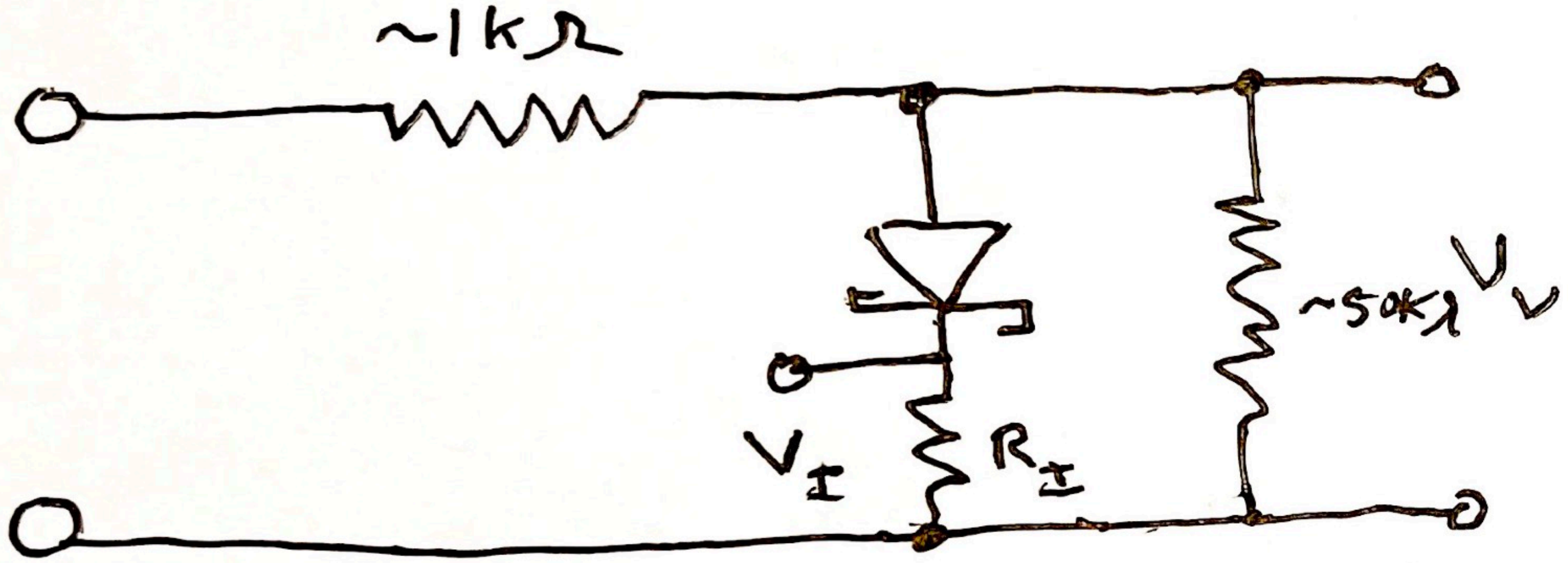
Preferred devices are recommended choices for future use and best overall value.

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

December, 2007 − Rev. 10

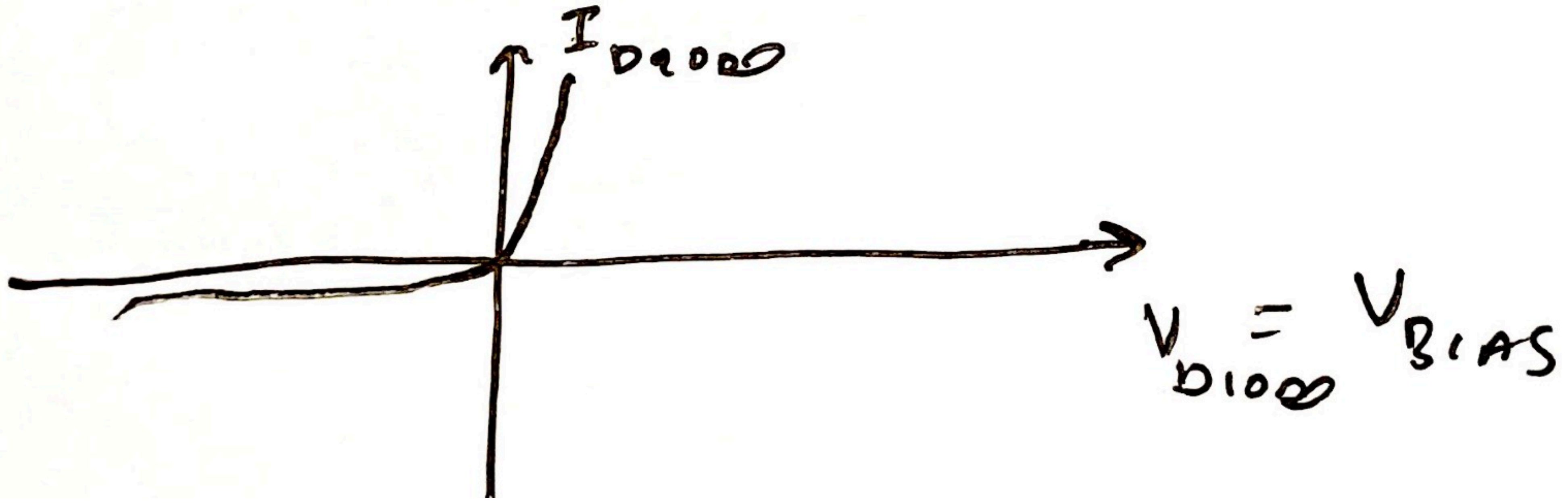
Publication Order Number:
1N5820/D

I-V Characteristics



$$V_{DIODE} = V_V - V_I$$

$$I_{DIODE} = V_I / R_I$$



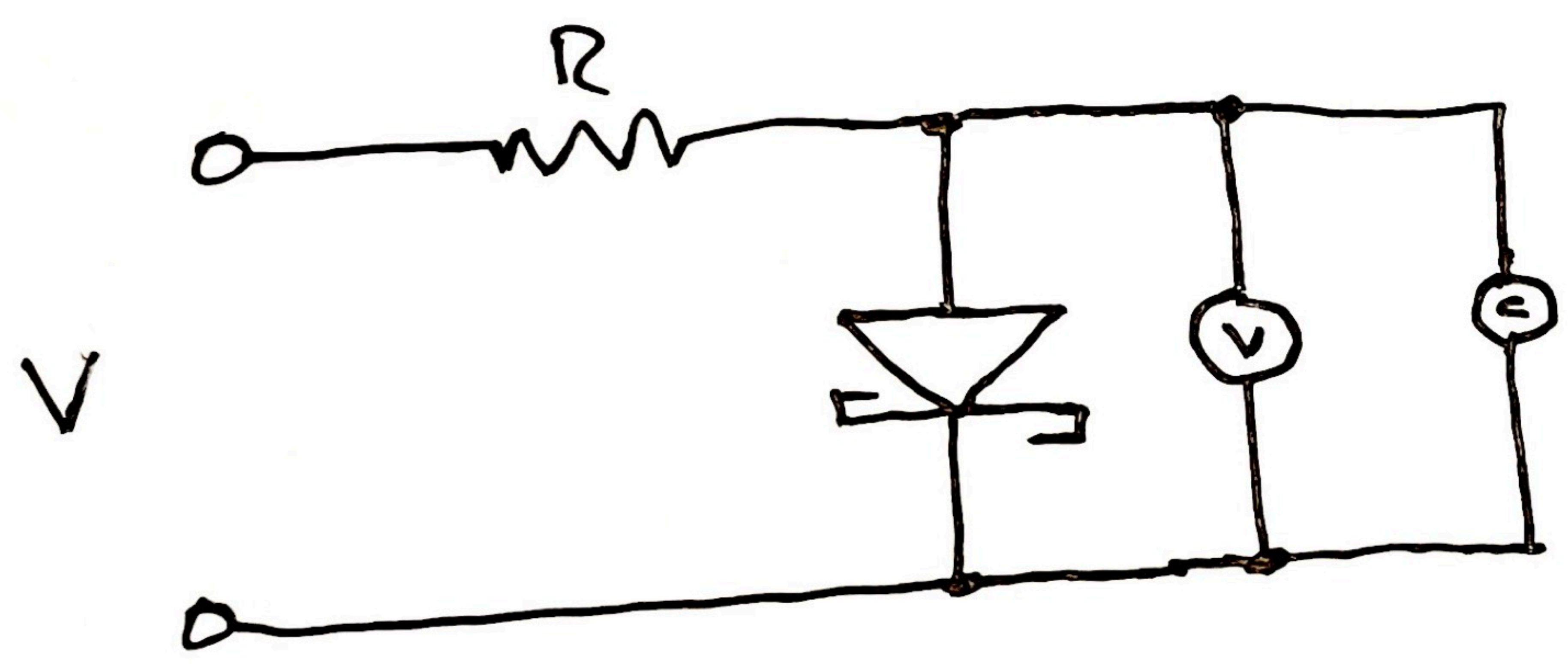
A^* = Richardson's constant

$= 1.2 \times 10^6$ A m^{-2} K^{-2} (x 2.2 for n-type)

$$I = I_S\left[\exp\left(\frac{qV_B}{nkT}\right) - 1\right] \quad I_S = AA^*T^2\exp(-q\phi_B/kT)$$

n = ideality factor

C-V Characteristics



MEASURE (V, C)

PLOT

$\frac{1}{C^2}$ vs V

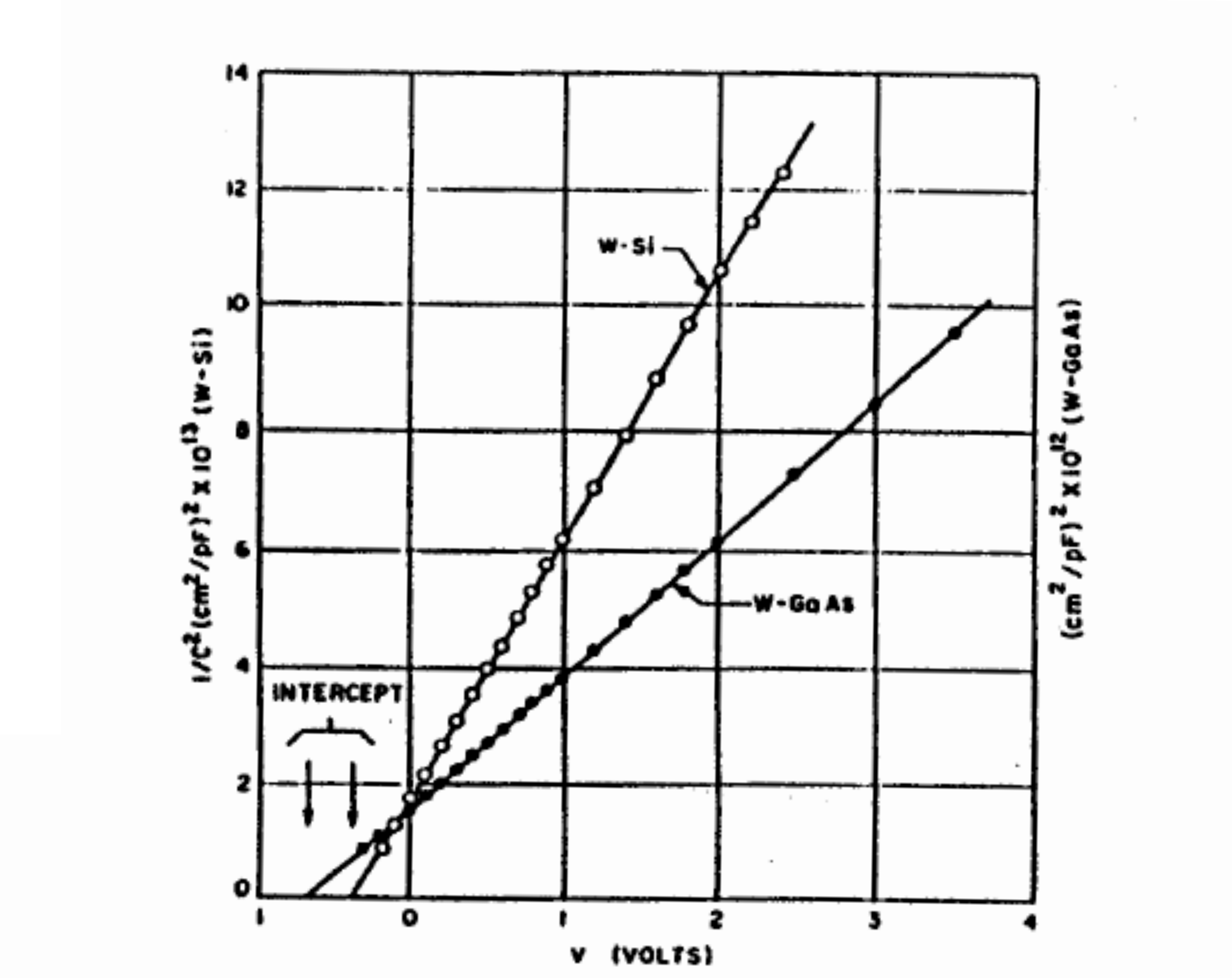


Fig. 28 1/C² versus applied voltage for W-Si and W-GaAs diodes. (After Crowell, Sarace, and Sze, Ref. 31.)

$$\frac{1}{C_m^2} = \frac{2(V_{bi} - V_i)}{q\varepsilon_s\varepsilon_o N_D A^2}$$

ε_S = relative dielectric constant = 11.68

Summary

- Measure I-V characteristics
  - Find “turn-on” voltage, ϕ_B
  - Find “ideality factor”
  - Can you see “ohmic limit”? Reverse breakdown voltage?
- Measure C-V characteristics
  - Find barrier height, ϕ_i
  - Find doping concentration, N_D