

CURRENT ELECTRICITY • SECTION 3.8

Temperature Dependence of Resistivity

Macroscopic models and microscopic mechanisms
for metals, alloys, and semiconductors.

MACROSCOPIC MATHEMATICAL MODEL

ρ_T : Final Resistivity at temperature T

$T - T_0$: Change in Temperature

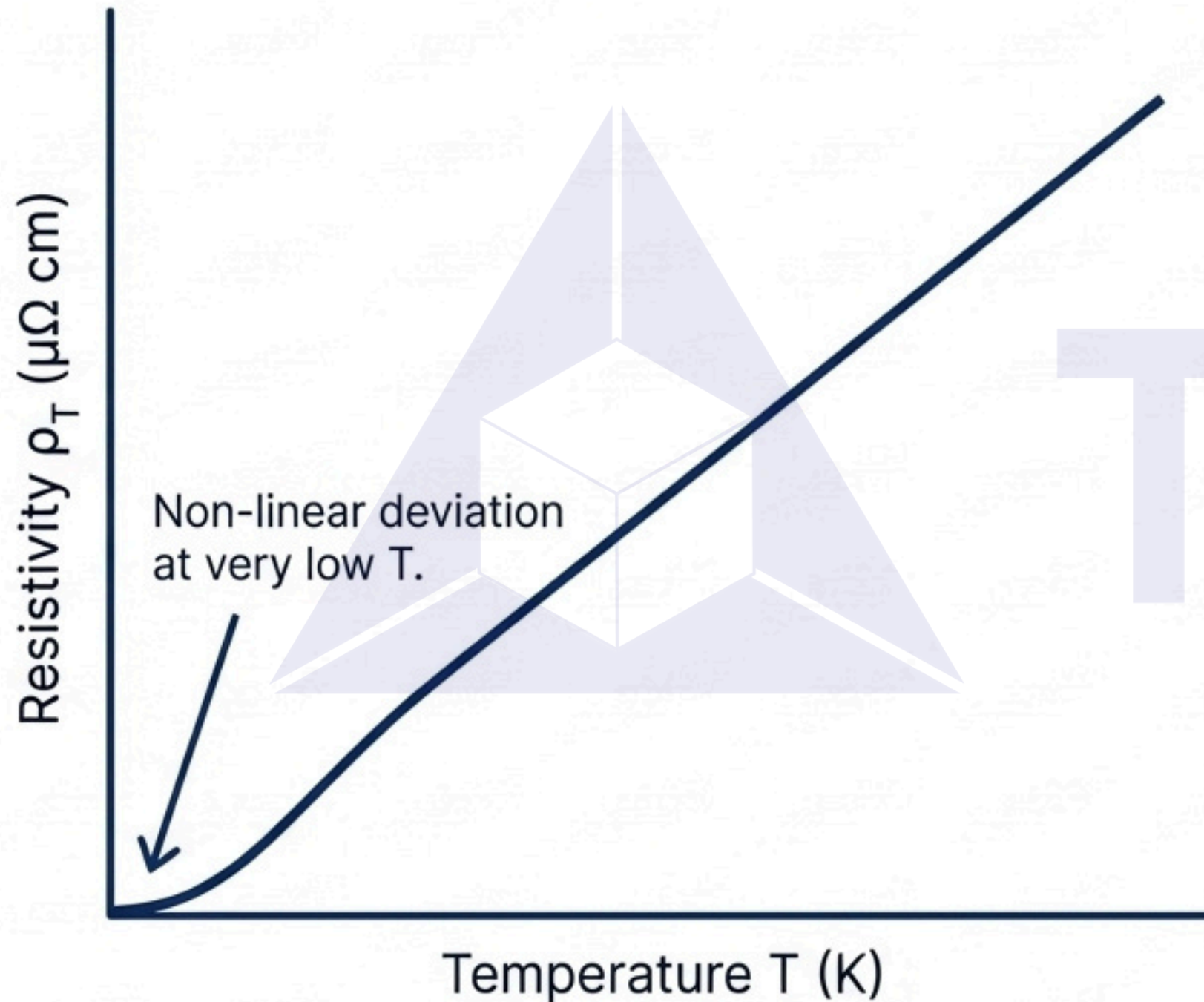
$$\rho_T = \rho_0 [1 + \alpha(T - T_0)]$$

ρ_0 : Reference Resistivity at reference temperature T_0

α : Temperature Coefficient of Resistivity

High-Yield Fact: α Dimension is $[\text{Temperature}]^{-1}$ (e.g., $^{\circ}\text{C}^{-1}$ or K^{-1})

Pure Metals: Increasing Resistivity



Microscopic Driver (α is Positive)

1. Temperature (T) Increases.



2. Number density (n) remains constant.
Thermal speed of electrons increases.

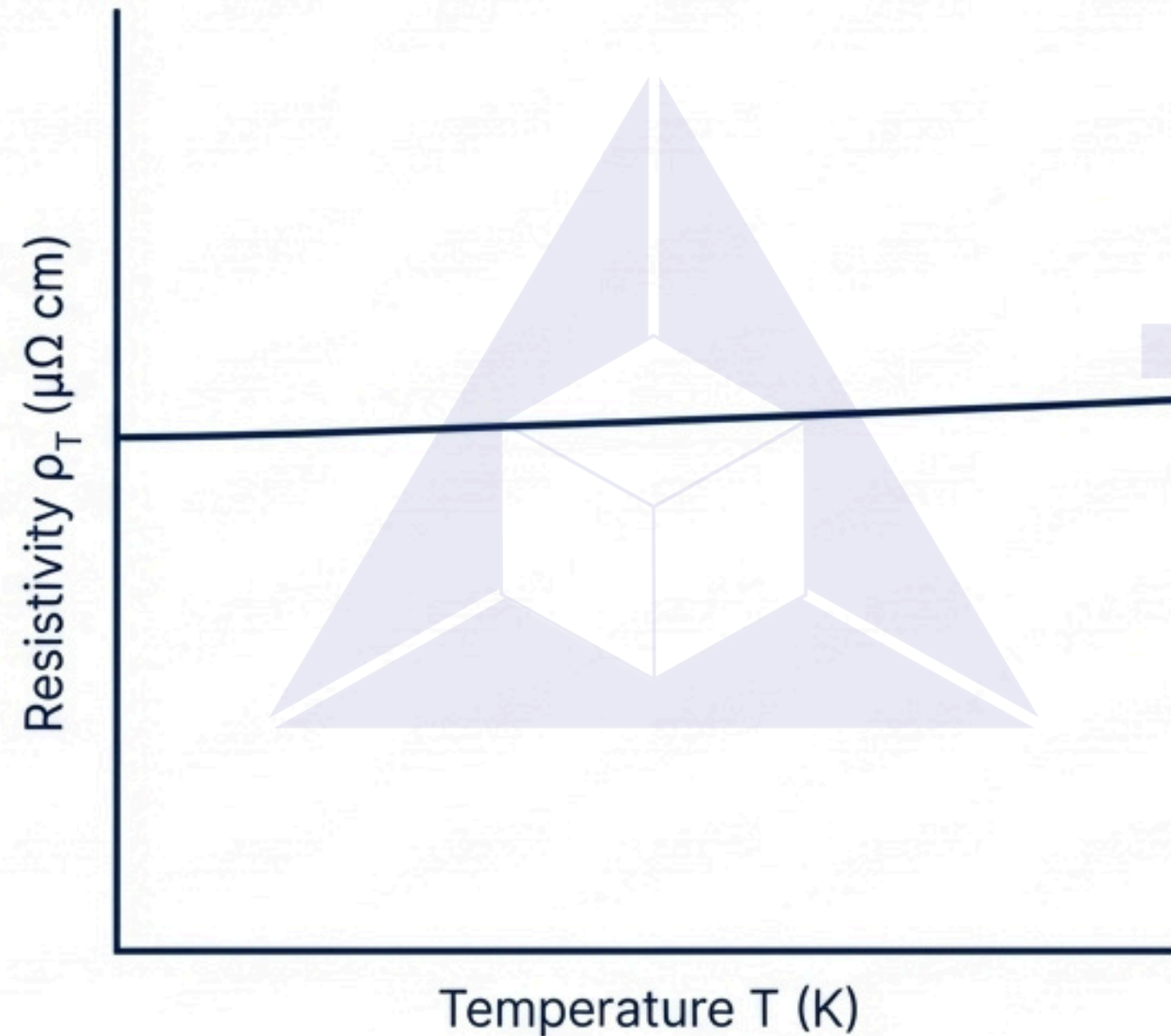


3. Collision frequency increases $\rightarrow$
Relaxation time (τ) DECREASES.



4. Result: Overall Resistivity (ρ)
INCREASES.

Alloys (Nichrome): Weak Dependence



Microscopic Behavior

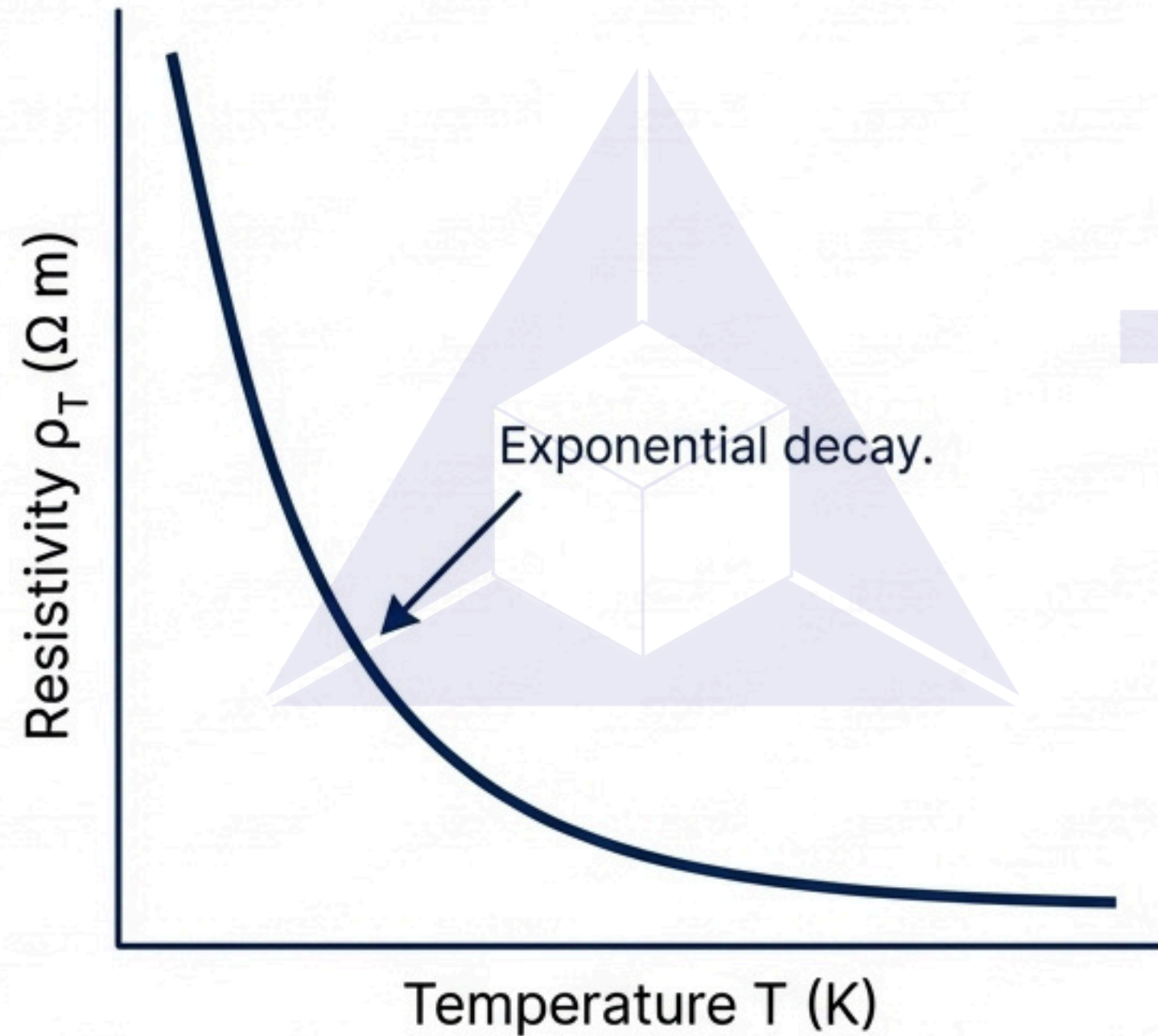
- α is near-zero (very small).
- Resistivity changes very little with temperature.
- High initial baseline resistivity.

Engineering Application

Common examples: Nichrome, Manganin, Constantan.

Widely used to manufacture standard wire-bound resistors because their resistance remains highly stable across temperature shifts.

Semiconductors: Decreasing Resistivity



Microscopic Driver (α is Negative)

1. Temperature (T) Increases.

2. Number density of free electrons (n) INCREASES exponentially.

3. This massive increase in n overcompensates for any slight decrease in relaxation time (τ).

4. Result: Overall Resistivity (ρ) DECREASES.

Key Takeaways: The Material Matrix

Material Type	Temp. Coefficient (α)	Microscopic Dominant Driver	Graph Profile
Metals (Copper, Silver)	Positive (+)	τ decreases	
Alloys (Nichrome, Manganin)	Near-Zero (≈ 0)	Weak overall dependence	
Semiconductors (Silicon, Germanium)	Negative (-)	n increases exponentially	