

Temperature-Dependent Hall Effect Analysis and Physics-Based Modeling of Indium Arsenide

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ABSTRACT

This paper presents a physics-based numerical framework for modeling Hall effect transport in n-type indium arsenide (InAs) using the van der Pauw configuration under sinusoidal electrical excitation. The framework is implemented in a numerical computing environment and captures the coupled relationships among drive current, magnetic flux density, specimen thickness, and the Hall coefficient over a wide range of electrical and thermal operating conditions. The model incorporates temperature-dependent bandgap narrowing via the Varshni relation, effective carrier mass, donor concentration, and mobility behavior following Matthiessen's rule, together with geometric attributes and operating variables such as magnetic-field strength, temperatures ranging from 200 K to 500 K, and time-varying excitation. The computational engine predicts temperature- and frequency-dependent transport quantities, including Hall voltage, carrier concentration, mobility, resistivity, conductivity, and the transit-time-limited cutoff frequency. The resulting framework provides a unified and reproducible computational tool that links microscopic transport physics to macroscopic device-level behavior and supports the analysis and design of InAs-based Hall devices without relying on empirical calibration.

Keywords: Indium arsenide, Hall voltage, Hall effect, mobility, numerical simulation, temperature-dependent transport.

1. INTRODUCTION

Indium arsenide (InAs) is a III-V compound semiconductor that has attracted extensive attention in both scientific and technological domains due to its exceptional electrical and structural properties. This material has a narrow direct bandgap of approximately 0.35 eV at room temperature, a low effective electron mass,

and an exceptionally high electron mobility exceeding 30,000 cm²/V·s. These characteristics enable rapid carrier transport and strong infrared sensitivity, making InAs a promising material for next-generation electronic and optoelectronic applications such as high-frequency transistors, infrared detectors, and photodiodes [1], [2]. Furthermore, InAs exhibits a surface electron accumulation layer and excellent lattice compatibility with GaSb and AlSb, which are advantageous for the fabrication of high-performance heterojunction devices.

Accurate determination of key transport parameters - such as carrier concentration, Hall coefficient, resistivity, and mobility - is essential for predicting and optimizing device performance. Among various characterization techniques, the Hall effect remains one of the most direct and reliable methods for probing carrier dynamics in semiconductors [3], [4]. Under an applied magnetic field, charge carriers experience a Lorentz force that generates a transverse potential difference known as the Hall voltage, from which fundamental transport parameters can be precisely determined. The van der Pauw Hall configuration, consisting of a square or arbitrarily shaped specimen with electrical contacts placed at its periphery, has become a preferred technique for precise semiconductor characterization. In this configuration, a constant current is driven diagonally between two adjacent contacts while a perpendicular magnetic field is applied; the resulting Hall voltage is measured across the opposite contacts. By performing multiple current-voltage permutations, both the resistivity and the Hall coefficient can be determined in accordance with the van der Pauw formalism [4]. This configuration is particularly advantageous for thin-film or irregularly shaped samples, as it allows the accurate extraction of transport parameters independent of sample geometry. Furthermore, by systematically varying the magnetic field, applied current, and temperature, carrier concentration and mobility can be precisely evaluated.

Although numerous studies have investigated III-V compound semiconductors, Hall effect measurements of InAs across a wide temperature range remain limited. Many reported studies have primarily focused on room-temperature behavior or narrow thermal ranges below 400 K [1], [5], thereby limiting the understanding of intrinsic transport mechanisms and temperature-dependent effects. Because temperature has a strong influence on carrier concentration, scattering processes, and band-structure parameters, a reliable modeling ap-

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proach should incorporate data spanning a wider temperature range to ensure accurate representation of thermal transport phenomena [6]. Moreover, practical Hall effect measurements can be time-consuming and costly, and are susceptible to misalignment or offset errors in the measurement setup [3]. These challenges emphasize the need for a robust numerical framework capable of reproducing and predicting Hall effect characteristics under diverse operating conditions [7], [8].

This study presents a physics-based numerical simulation framework, implemented in MATLAB, for modeling Hall effect transport in n-type InAs using the van der Pauw method and calibrated with reference data [9], [10]. The model incorporates temperature-dependent material parameters, including bandgap narrowing governed by the Varshni relation [11], effective mass variation, and mobility degradation described by Matthiessen's rule [12], combined with geometric and operational factors such as sample thickness, magnetic flux density, and drive current. The framework enables temperature sweeps from 200 K to 500 K and supports both steady-state and sinusoidal electrical excitation for dynamic analysis. From the simulation, key transport quantities—including Hall voltage, Hall coefficient, carrier concentration, resistivity, conductivity, and cutoff frequency are obtained as functions of temperature and excitation level. The proposed van der Pauw-based model effectively captures the coupled dependencies between electrical and magnetic parameters [13]. The integrated approach provides a comprehensive, predictive tool that links microscopic carrier transport to macroscopic device performance, offering valuable insight for the design and optimization of InAs-based electronic and optoelectronic devices under varying electrical and thermal conditions.

2. THEORY

The Hall effect provides a rigorous, quantitative methodology for relating microscopic carrier transport phenomena to macroscopic device performance metrics. The measurable Hall voltage serves as the foundation for deriving a hierarchy of interdependent material and device parameters. The theoretical model implemented in this work follows a systematic framework that begins with the Hall voltage formulation and extends to band structure, carrier statistics, mobility behavior, and high-frequency transport limits, with all quantities consistently defined under the van der Pauw formalism [13].

2.1 Hall Voltage and Hall Coefficient

The Hall voltage is defined as

$$V_H = \frac{R_H I B}{d} \quad (1)$$

where V_H is the Hall voltage, I is the applied current, B is the magnetic flux density, d is the sample thickness, and R_H is the Hall coefficient. The Hall coefficient expresses the proportionality between the measured Hall

voltage and the product of the magnetic field and current density [13]. For a single-carrier semiconductor, it is given by

$$R_H = \frac{1}{qn(T)} \quad (2)$$

where q is the elementary electronic charge and $n(T)$ is the temperature-dependent carrier concentration that any variation in carrier density directly modifies the Hall response—hence temperature and doping level become critical factors governing the measured voltage [2], [6], [12].

2.2 Bandgap Narrowing and Temperature Dependence

The carrier concentration depends strongly on the semiconductor bandgap, which decreases with temperature due to lattice expansion and electron-phonon interactions. This behavior is described by the Varshni relation [11]:

$$E_g(T) = E_{g0} - \frac{\alpha T^2}{T + \beta} \quad (3)$$

where $E_g(T)$ is the bandgap at temperature T , E_{g0} is the bandgap at 0 K, and α, β are material constants. In this model, $\alpha = 2.76 \times 10^{-4}$ eV/K and $\beta = 93$ K are used for InAs. As T increases, the reduction in E_g lowers the energy barrier for thermal excitation, thereby enhancing the carrier population and electrical conductivity.

2.3 Carrier Concentration and Intrinsic Behavior

The carrier concentration $n(T)$ obtained from the measured Hall coefficient in the van der Pauw configuration can be expressed as:

$$n(T) = \frac{N_D + \sqrt{N_D^2 + 4n_i(T)^2}}{2} \quad (4)$$

where $n_i(T)$ is the intrinsic carrier concentration. The intrinsic carrier concentration represents the density of thermally generated electron-hole pairs in a semiconductor without intentional doping (undoped) [11], [12]. It depends on both the bandgap and lattice temperature and increases exponentially with temperature due to thermal excitation across the bandgap. The intrinsic carrier concentration is expressed as

$$n_i(T) = \sqrt{N_C(T)N_V(T)} \exp\left(-\frac{E_g(T)}{2k_B T}\right) \quad (5)$$

with k_B being the Boltzmann constant ($k_B = 1.381 \times 10^{-23}$ J/K = 8.617×10^{-5} eV/K). The conduction- and valence-band effective density of states, $N_C(T)$ and $N_V(T)$, describe the available quantum states for carriers, which are given by

$$N_C(T) = 2 \left(\frac{2\pi m_e^* k_B T}{h^2} \right)^{3/2} \quad (6)$$

$$N_v(T) = 2 \left(\frac{2\pi m_h^* k_B T}{h^2} \right)^{3/2} \quad (7)$$

where $m_e^* = 0.023m_0$ and $m_h^* = 0.41m_0$ are the effective electron and hole masses, respectively ($m_0 = 9.11 \times 10^{-31}$ kg), and $h = 6.626 \times 10^{-34}$ J/s is Planck's constant.

2.4 Carrier Mobility and Scattering Mechanisms

Carrier mobility $\mu(T)$ reflects how efficiently electrons move under an electric field and is a key determinant of conductivity and device speed. In semiconductors, mobility decreases with increasing temperature because of competing scattering processes. At low temperatures, ionized impurity scattering dominates, whereas at higher temperatures, lattice (phonon) scattering becomes the limiting mechanism. The total mobility is described using Matthiessen's rule:

$$\frac{1}{\mu(T)} = \frac{1}{\mu_{ph}(T)} + \frac{1}{\mu_{ii}(T)} \quad (8)$$

where $\mu_{ph}(T)$ and $\mu_{ii}(T)$ correspond to phonon-limited and ionized-impurity-limited mobility components, respectively. These temperature dependencies are modeled as

$$\mu_{ph}(T) = \mu_{ph0} \left(\frac{T}{T_0} \right)^{-m_{ph}} \quad (9)$$

$$\mu_{ii}(T) = \mu_{ii0} \left(\frac{T}{T_0} \right)^{-m_{ii}} \quad (10)$$

with μ_{ph0}, μ_{ii0} as reference mobilities at T_0 . The parameter T_0 denotes the reference temperature, typically chosen as 300 K (room temperature), at which the mobilities μ_{ph0} and μ_{ii0} are defined. In this model, the scattering exponents are set to $m_{ph} = 1.5$ and $m_{ii} = -1.5$. Here, m_{ph} and m_{ii} are empirical parameters that quantify the strength of the temperature dependence of phonon-limited and ionized-impurity-limited scattering, respectively [6], [12].

2.5 Conductivity, Resistivity, and High-Frequency Transport

Conductivity and resistivity, as extracted from the van der Pauw relation [4], [13], are expressed as

$$\sigma(T) = qn(T)\mu(T) \quad (11)$$

$$\rho(T) = \frac{1}{\sigma(T)} \quad (12)$$

which link microscopic transport to macroscopic electrical behavior. Furthermore, mobility governs the transit-time-limited cutoff frequency [14], [15]:

$$f_c(T) = \frac{\mu(T)V_{DS}}{2\pi L^2} \quad (13)$$

where V_{DS} is the applied drain-source voltage ($V_{DS} = 1.0$ V) and L is the channel length ($L = 200$ nm) as a representative nanoscale parameter to obtain physically meaningful cutoff-frequency estimates. The value

provides a realistic device-scale dimension for transit-time calculations and demonstrates the scalability of the transport model to nanoscale conditions. The cutoff frequency represents the maximum frequency at which a device can operate effectively, limited by the carrier transit time across the channel [16]. It is a critical performance metric in RF and high-speed logic devices.

2.6 Model Validation and Error Evaluation

To evaluate model accuracy, the root mean square error (RMSE) between experimental and simulated Hall voltages is defined as

$$Error_{RMSE}(\%) = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^N (V_{H,meas}(i) - V_{H,sim}(i))^2}}{\text{mean}(V_{H,meas})} \times 100 \quad (14)$$

where $V_{H,meas}$ and $V_{H,sim}$ are measured and simulated Hall voltages, respectively, and N is the number of data points. This error metric quantifies the degree of agreement between experiment and simulation, ensuring that the developed physics-based framework accurately reproduces observed Hall effect behavior across the examined temperature range [17].

3. EXPERIMENTS

3.1 Experimental Procedure

Hall effect measurements were performed on n-type InAs samples using the van der Pauw configuration, a widely recognized technique for determining carrier transport parameters in semiconductors of arbitrary geometry. In this arrangement, a constant current (I) was driven diagonally between two adjacent contacts on the specimen, while a perpendicular magnetic flux density (B) was applied normal to the sample plane. The Lorentz force deflected charge carriers toward one edge of the specimen, inducing a measurable transverse Hall voltage (V_H) across the opposite contacts. Multiple current-voltage permutations were recorded to compensate for geometric asymmetry and contact misalignment, while longitudinal voltage drops were used to determine resistivity in accordance with the van der Pauw relation [13]. The experimental setup is illustrated in Fig. 1(a) shows the circuit schematic of the van der Pauw Hall effect measurement configuration for current injection and Hall voltage measurement, while Fig. 1(b) presents the complete experimental setup, including the electromagnet, measurement unit, constant current power supply, Gauss-Tesla meter, and data acquisition software. A uniform magnetic field of 0.03 T was generated by the electromagnet, and a programmable current source supplied currents ranging from 0 A to 1.4 A. Measurements were conducted at room temperature on three n-type InAs samples with slightly different thicknesses to verify reproducibility and evaluate geometric effects, as summarized in Table

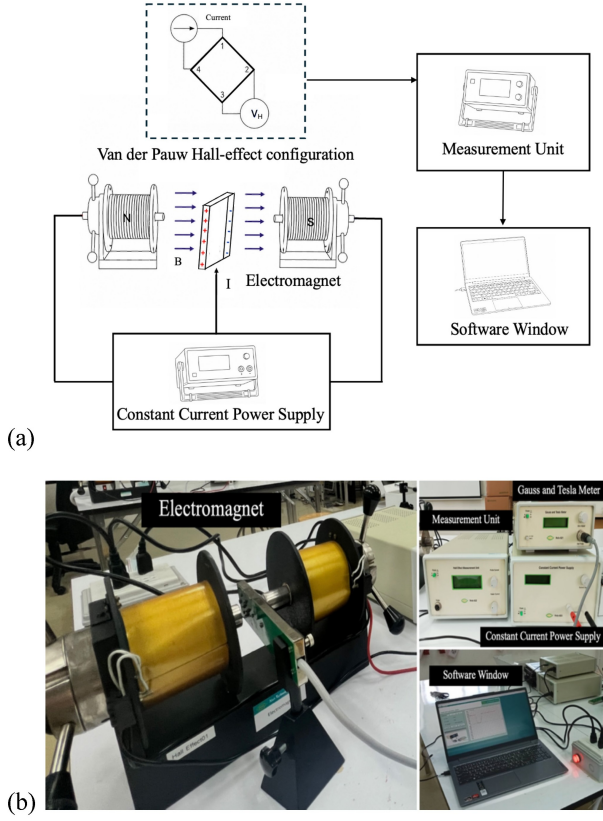


Fig. 1: (a) Circuit schematic of the van der Pauw Hall effect measurement configuration showing current injection and Hall voltage measurement; (b) The experimental setup.

1. To minimize systematic errors, residual offsets, stress-induced voltages, and probe misalignment were carefully monitored and corrected in accordance with standard Hall metrology practices [3], [14]. The measured Hall voltages were subsequently converted into the Hall coefficient (R_H) and carrier concentration (n) using the governing equations presented in Section 2. The carrier concentration was then obtained from the inverse relationship between the Hall coefficient and charge density for a single-carrier semiconductor. All calculations were performed using measured values of Hall voltage, applied current, magnetic flux density, and sample thickness under the van der Pauw configuration.

3.2 Simulation Framework

A physics-based Hall effect model corresponding to the van der Pauw geometry was implemented in MATLAB. The workflow was designed to ensure reproducibility and transparency in parameter handling. Input variables included the applied current (I), magnetic flux density (B), and sample thickness (d), complemented by material-specific parameters such as effective carrier mass, Varshni bandgap coefficients, and mobility scattering exponents [11], [12]. The simulation incorporated the governing relations for Hall voltage, Hall coefficient,

Table 1: Physical and Electrical Parameters of InAs Samples.

No.	Sample name	d [mm]	A [mm ²]	N_D [cm ⁻³]	μ_0 [cm ² /V·s]
1	Real#1	0.75	25	1.1×10^{15}	3.16×10^3
2	Real#2	0.60	36		
3	Real#3	0.65	42		

carrier concentration, temperature-dependent bandgap narrowing, and Matthiessen's rule for mobility. The model implementation adhered to standard Hall effect measurement conventions. The computed outputs included the Hall voltage (V_H), carrier concentration (n), mobility (μ), resistivity (ρ), conductivity (σ), and cutoff frequency (f_c). Calibration was initially performed at 300 K by tuning the donor concentration (N_D) and reference mobility (μ_0) to minimize deviation between measured and simulated Hall voltages. The model used a Simulink-based block-and-lookup-table architecture following a loop-measurement configuration for iterative computation [9], [10]. Calibration was performed at 300 K using a loop-measurement configuration, in which simulated Hall voltages were iteratively compared with experimental measurements for three InAs samples with different thicknesses. The donor concentration and reference mobility were adjusted until the simulated curves closely matched the measured V_H - I characteristics, minimizing both the slope and offset deviations. Once the calibration achieved convergence, these parameters remained fixed for subsequent temperature-dependent simulations to preserve physical validity. The iterative calibration process defined convergence when the relative root mean square error (RMSE) between measured and simulated Hall voltage values fell below 5% over the full current range.

After calibration, the framework was extended to predict temperature-dependent behavior over the range of 200-500 K through the following sequence: (i) computing bandgap narrowing using the Varshni relation to obtain $E_g(T)$, (ii) calculating intrinsic and extrinsic carrier concentrations $n(T)$, (iii) evaluating mobility degradation $\mu(T)$ based on phonon and impurity scattering, and (iv) determining resistivity, conductivity, and cutoff frequency from the derived parameters [12], [17]. The temperature-sweep simulations successfully reproduced the experimentally observed trends, demonstrating the model's ability to capture the interdependence of electrical, thermal, and magnetic phenomena with high physical fidelity [1], [6], [17].

3.3 Comparative Analysis

The comparison between experimental and simulated results was conducted in stages:

• Calibration at 300 K:

The simulated Hall voltages exhibited strong agreement with the experimental data, with an average root mean square error (RMSE) below 5%. This confirms

the validity and numerical stability of the model under baseline conditions [1], [2], [12].

- **Temperature Extension (200-500 K):**

The model successfully reproduced the characteristic semiconductor transport trends specifically: the exponential increase in carrier concentration with temperature and the power-law decrease in mobility dominated by phonon scattering. Across the temperature range up to 500 K, the prediction deviation remained within 5%, which aligns with error margins reported in comparable Hall effect investigations [1], [2], [6], [18].

The combined experimental-simulation methodology, anchored by the van der Pauw configuration illustrated in Fig. 1, ensures both quantitative accuracy and predictive robustness. Experimental validation provides a physical benchmark for the theoretical framework, whereas the simulation extends its applicability to thermal conditions that are otherwise difficult or costly to realize experimentally. Together, this integrated approach establishes a reliable and practical tool for analyzing and predicting the performance of InAs-based devices across diverse electrical and thermal environments.

4. RESULTS AND DISCUSSION

Hall effect measurements were performed on n-type indium arsenide (InAs) samples to validate the accuracy of the developed numerical simulation framework. A uniform magnetic field of 0.03 T was applied perpendicular to the current path while the drive current was gradually increased from 0 A to 1.4 A. The measured Hall voltage, shown in Fig. 2 (a), exhibited a strictly linear dependence on the applied current throughout the measurement range. This linearity confirms that electron transport follows classical single-carrier conduction under the Lorentz force. It also demonstrates that the Hall voltage scales proportionally with both current and magnetic flux density, and inversely with sample thickness, validating the precision of the contact geometry and uniformity of the applied magnetic field [18]-[20]. The absence of noticeable nonlinearity or voltage offset further indicates that thermal drift, contact resistance, and probe misalignment were effectively minimized during the experiment [3], [13], [15].

The simulation reproduced this linear response with high fidelity, as illustrated in Fig. 2 (b). The mean deviation between experimental and simulated data remained below 5%, confirming the quantitative reliability of the model. This close agreement suggests that the calibrated parameters-carrier concentration, donor density, effective mass, and electron mobility-accurately represent the physical properties of InAs at 300 K, consistent with established literature on temperature-stable electron transport in III-V narrow-gap materials [11], [12], [17]. The lookup-table-based uses the lookup table to map the coupled relationship among current, magnetic field, temperature, and sample geometry to the corresponding Hall voltage output. The simulation constructs this table from measured and calculated Hall voltage data

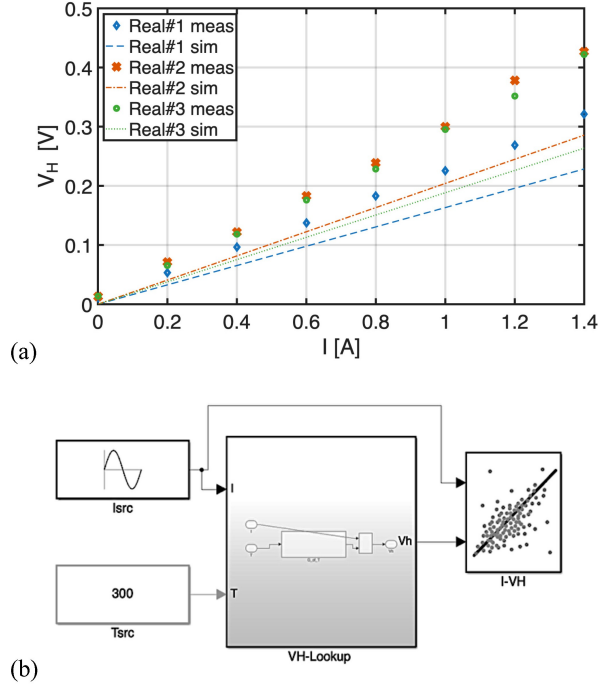


Fig. 2: Room-temperature Hall validation and Simulation (van der Pauw). (a) Linear $I - V_H$ characteristics for three InAs specimens (Real#1-Real#3) with differing thickness. (b) Simulink block and lookup-table architecture for calculating V_H from the physics-based Hall model using I , T , B , and sample geometry.

and applies interpolation to estimate intermediate values across the operating range. This implementation allows the model to capture the multiphysics coupling among electrical, magnetic, thermal, and geometric parameters while maintaining strong numerical stability during time-domain simulations. The lookup-table framework also explains the model's ability to reproduce both the amplitude and slope of the measured I-V characteristics. Accurate mapping between input parameters and Hall voltage ensures consistent magnetic-field distribution and correct geometric representation within the simulation domain, which leads to close agreement between simulated and experimental responses [4], [13], [16]. The model employs a sinusoidal excitation waveform to represent realistic dynamic operating conditions and to evaluate system behavior under continuously varying electrical input. The sinusoidal signal provides smooth and periodic variation in current, which improves numerical convergence and reveals the sensitivity of the Hall voltage to changing input conditions. In addition, temperature strongly influences carrier mobility through enhanced lattice vibrations and electron-phonon interactions. The sinusoidal input enables the model to track temperature-dependent changes in Hall voltage continuously over time and to evaluate how thermal effects interact with electrical excitation. Extending the framework to the temperature range of 200–500

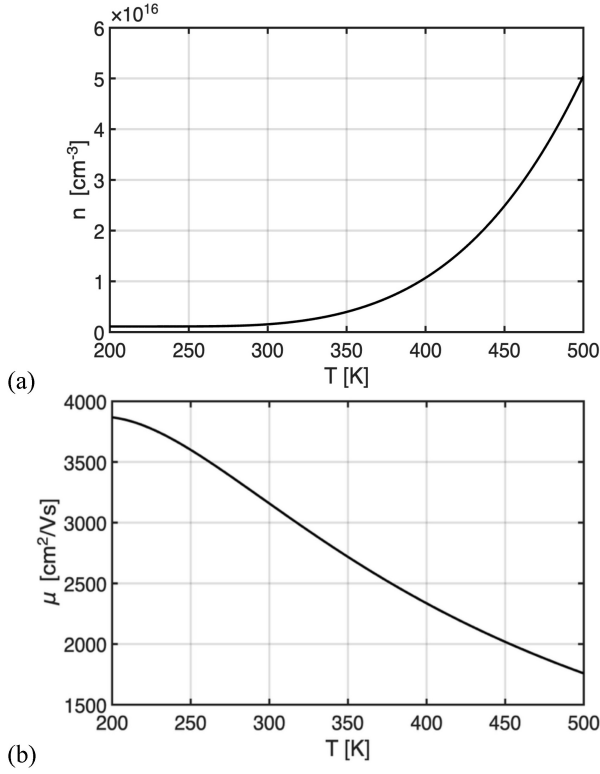


Fig. 3: Temperature-dependent transport parameters. (a) Carrier concentration $n(T)$ showing extrinsic-to-mixed transition driven by Varshni bandgap narrowing and the intrinsic term $n_i(T)$. (b) Mobility $\mu(T)$ decreasing with T per Matthiessen's rule (phonon-limited at high T , ionized impurity contribution at low T).

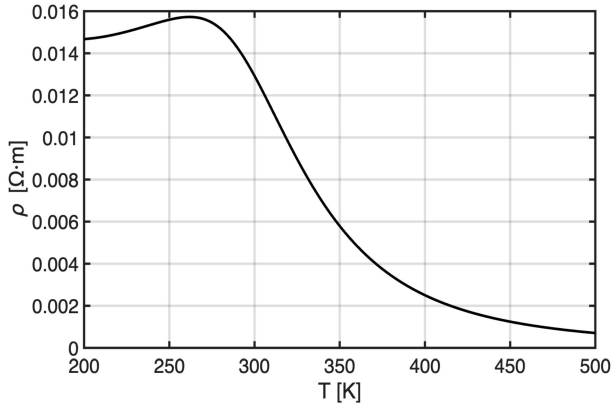


Fig. 4: Resistivity versus temperature. Overall decrease as the rise in carrier concentration outweighs mobility degradation.

K revealed distinct temperature-dependent transport behaviors, summarized in Fig. 3 (a). The carrier concentration increased exponentially with temperature, consistent with thermally induced bandgap narrowing and enhanced intrinsic carrier generation. The gradual transition from extrinsic conduction at low temperatures to mixed or intrinsic conduction at higher temperatures

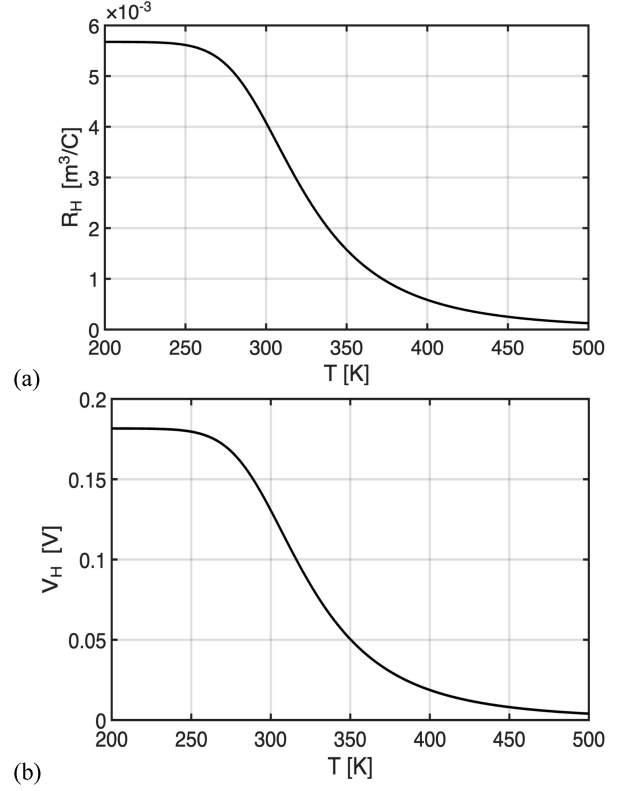


Fig. 5: Hall-specific metrics versus temperature: (a) Hall coefficient; (b) Hall voltage under fixed current, magnetic field, and thickness.

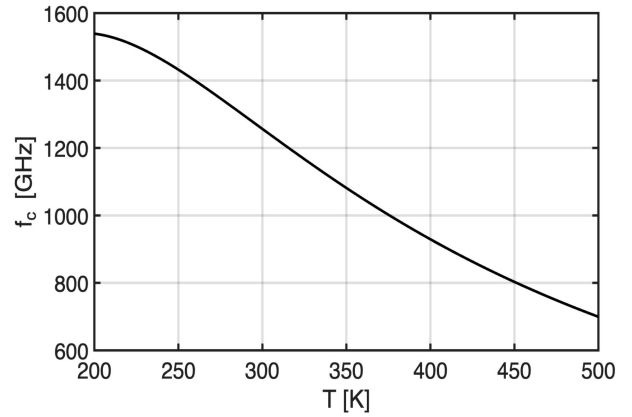


Fig. 6: Transit-time-limited cutoff frequency versus temperature.

reflects the strong temperature sensitivity of InAs. Because of its narrow bandgap, carrier activation occurs even under moderate thermal excitation. As temperature rises, the Fermi level shifts toward the midgap, reducing donor-state dominance and enabling intrinsic excitation above approximately 350 K. This marks the onset of temperature-driven conduction enhancement characteristic of narrow-gap III-V semiconductors [11], [17], [19], [20]. The electron mobility decreased monotonically with temperature, as shown in Fig. 3 (b). This

reduction originates from enhanced phonon scattering, which limits carrier drift velocity as lattice vibrations intensify. At low temperatures, impurity scattering dominates, whereas at higher temperatures, acoustic and optical phonon scattering prevail, shortening the mean free path of electrons. The interplay between increasing carrier density and decreasing mobility defines the fundamental transport behavior of InAs. Although these effects act in opposition, the exponential increase in carrier concentration predominates, yielding a net rise in conductivity. This relationship is evident in Fig. 4, which presents the temperature dependence of conductivity and resistivity. Conductivity gradually increases with temperature, while resistivity decreases correspondingly. The continuous, smooth variation indicates a stable carrier-generation process without abrupt phase transitions or structural instabilities. Around 400-450 K, the electrical conductivity begins to show a slight saturation trend, indicating that mobility degradation increasingly counteracts the effect of thermally generated carriers. At higher temperatures, optical phonon scattering dominates the carrier-scattering process in indium arsenide (InAs). Stronger lattice vibrations intensify electron-phonon interactions and progressively reduce carrier mobility as temperature increases. Although thermal excitation continues to raise carrier concentration, the mobility loss caused by optical phonon scattering restricts further growth in conductivity and leads to the observed saturation behavior. An asymptotic trend also signals that the material moves toward a fully intrinsic regime, where both electrons and holes contribute to electrical conduction at comparable levels [19], [20].

Hall-specific quantities further substantiate these findings. As displayed in Fig. 5 (a), the Hall coefficient decreases steadily with temperature, following its inverse dependence on carrier density. The corresponding Hall voltage, shown in Fig. 5 (b), exhibits the same downward trend, reflecting reduced Hall sensitivity. Physically, as more electrons are thermally generated, the Lorentz force distributes across a larger carrier population, lowering the net transverse potential. The persistence of a negative Hall voltage over the entire range confirms that electrons remain the dominant charge carriers, with no conduction-type inversion even up to 500 K.

At the device level, Fig. 6 illustrates the temperature dependence of the transit-time-limited cutoff frequency. The cutoff frequency decreases smoothly with increasing temperature, indicating the strong influence of phonon scattering on high-frequency response. The decline from the terahertz range at low temperature to the sub-terahertz regime near 500 K highlights the trade-off between increased conductivity and reduced carrier velocity. This finding underscores that while InAs maintains high transport capability, its high-speed performance deteriorates under thermal excitation due to mobility degradation. Such behavior is especially relevant for InAs-based infrared detectors, Hall sensors, and RF amplifiers, where thermal stability and carrier

dynamics govern overall performance [21], [22].

Collectively, the results present a coherent and physically consistent picture of Hall transport in n-type InAs. The developed model successfully reproduces the linear Hall voltage response, temperature-driven carrier activation, phonon-limited mobility degradation, and corresponding variations in conductivity, resistivity, Hall coefficient, and cutoff frequency. These findings confirm that the proposed numerical simulation framework accurately captures both microscopic transport mechanisms and their macroscopic manifestations, providing a robust, predictive tool for analyzing InAs-based electronic and optoelectronic devices across a wide thermal spectrum [21]-[24].

5. CONCLUSIONS

This study develops and validates an integrated experimental-simulation framework to analyze Hall effect transport in n-type indium arsenide (InAs). Using high-precision experimental data for calibration, the physics-based model reproduces the coupled relationship among drive current, magnetic flux density, and sample geometry with quantitative agreement within 5%. The measured linear dependence of Hall voltage on current at room temperature confirms classical single-carrier conduction dominated by electrons, consistent with the Lorentz-force mechanism and a uniform magnetic-field distribution. The model directly links microscopic carrier dynamics to macroscopic voltage behavior, strengthening confidence in both the experimental configuration and the numerical implementation. Across the temperature range of 200-500 K, the framework captures the transition from extrinsic to intrinsic transport regimes in InAs. At low temperatures, electrons from ionized donor impurities dominate conduction, with the Fermi level remaining near the conduction band. As temperature increases, thermal excitation generates additional electron-hole pairs, narrows the bandgap, and shifts the Fermi level toward the midgap. Around 350 K, intrinsic carriers reach a level comparable to donor-derived carriers, creating a mixed-conduction regime in which both carrier types contribute to current flow. At higher temperatures, intrinsic carriers dominate transport and produce nearly balanced electron and hole concentrations. This transition explains the exponential increase in carrier concentration, the monotonic decrease in the Hall coefficient, and the stable electrical behavior observed across the investigated thermal range. The simulation predicts a temperature-dependent reduction in carrier mobility consistent with phonon-limited scattering described by Matthiessen's rule. The model shows that conductivity remains high because the increase in carrier density outweighs the mobility loss. The calculated Hall coefficient and Hall voltage decrease steadily with temperature, reflecting reduced Hall sensitivity as the carrier population expands. At the device level, the computed cutoff frequency decreases from the terahertz domain at low temperature to the sub-terahertz range near 500 K,

demonstrating the impact of phonon scattering on high-frequency operation. The results demonstrate that the proposed framework provides a reliable and predictive tool for analyzing temperature-dependent transport behavior and for supporting the design and performance evaluation of InAs-based electronic and optoelectronic devices operating under varying thermal conditions.

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