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THE V-I CHARACTERISTICS OF TWO-LAYER SEMICONDUCTOR COMPONENTS ARE DRAWED WITH LABVIEW

Đặc tuyến V-I của linh kiện bán dẫn hai lớp được vẽ bằng LabView

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ABSTRACT

This study endeavors to elucidate the attributes of two-layer semiconductor components by leveraging the voltage-current equation as the foundational framework. The voltage-current (V-I) characteristics serve as a critical conduit for expounding the operational principles, particularly discerning the pivotal voltage thresholds in a more concise and perspicuous manner. The conventional modus operandi for simulating the V-I characteristics of two-layer semiconductor components is hitherto conducted through the utilization of LabView, aligning seamlessly with the V-I equation governing such semiconductor configurations.

Keywords: *V-I characteristic, two layers semiconductor components, working principle, V-I equation.*

TÓM TẮT

Nghiên cứu này nỗ lực làm cho rõ thuộc tính của linh kiện bán dẫn hai lớp bằng cách phân tích, vẽ ra phương trình điện áp-dòng điện (V-I) là phần kiến thức nền tảng. Đặc tuyến điện áp-dòng điện (V-I) đóng vai trò là đồ thị quan trọng nhằm giải thích nguyên lý hoạt động, đặc biệt là phân biệt các ngưỡng điện áp một cách ngắn gọn và dễ hiểu hơn. Phương pháp để mô phỏng đặc tuyến V-I của linh kiện bán dẫn hai lớp hiện nay được thực hiện thông qua việc sử dụng phần mềm LabView, là dựa trên phương trình V-I chi phối cấu trúc linh kiện bán dẫn 2 lớp đó.

Từ khóa: *đặc tuyến V-I, linh kiện bán dẫn hai lớp, nguyên lý hoạt động, phương trình V-I.*

1. Introduction

In the field of electronics, semiconductor technology has undeniably catalyzed a profound revolution. Within this expansive domain, two-layer semiconductor components have emerged as pivotal entities with a plethora of pragmatic applications, including but not limited to diodes, light-emitting diodes (LEDs), Zener diodes, and 7-segment LED displays. The foundational architecture of these two-layer semiconductor components revolves around the establishment of a P-N junction - a juncture wherein a positive semiconductor interfaces with its negative counterpart. Notably, the defining characteristic of the P-N junction resides in its rectifying behavior, permitting the passage of electric current exclusively in the forward-biased direction. Conversely, when subjected to reverse-biased conditions, the P-N junction exhibits an impedance to

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current flow, resulting in a near-zero current traversing through the junction. This inherent behavior renders the P-N junction akin to a "valve" wherein current regulation is distinctly demarcated. The voltage-current (V-I) characteristics of two-layer semiconductor components, therefore, serve as an invaluable tool for elucidating the distinctive attributes of these components. One such attribute is the determination of the opening voltage, colloquially referred to as the threshold voltage, which assumes paramount significance in characterizing the operational status of two-layer semiconductor components.

The prevailing approach for characterizing semiconductor components is commonly referred to as the Voltage Sweep Method, which entails the systematic application of a variable voltage across the component under examination while concurrently monitoring the ensuing current response. Subsequently, a comprehensive characteristic curve is constructed by interconnecting the gathered voltage and current data points. Employing an oscilloscope as the instrumentation of choice facilitates the precise measurement of Voltage-Current (V-I) characteristics for semiconductor components. It is imperative to acknowledge, however, that this method, when applied to actual physical components, may be susceptible to errors contingent upon real-world operating conditions. Additionally, the execution of this method typically incurs substantial financial expenditure.

In contrast, LabView software presents an alternative solution for the measurement and plotting of characteristic curves without necessitating the deployment of physical components. Concurrently, Proteus software, equipped with a user-friendly Graph function, offers a simulation approach that is more straightforward and obviates the need for intricate programming, as compared to LabView [1].

Nevertheless, it is essential to underscore that LabView furnishes a more profound comprehension of the theoretical underpinnings of semiconductor components, encompassing critical elements such as expressions elucidating the current's dependency on varying voltage and the internal coefficients embedded within these expressions. Furthermore, LabView empowers engineers with the capability to adjust these coefficients, thereby enhancing their understanding of their functional significance and honing their programming acumen - a skill set of paramount importance within the engineering domain. This highlights the unequivocal advantage of employing LabView, particularly in an educational context, as it equips students with a comprehensive understanding and cultivates advanced programming skills, thereby underscoring the pivotal role of theoretical knowledge and programming proficiency in the realm of engineering.

The operational efficiency of LabView is notably enhanced through the utilization of its graphical programming language, commonly referred to as G code [2]. NI LabView stands out as a specialized graphical development environment meticulously crafted to cater to the specific needs of engineers and scientists. In direct comparison to conventional text-based programming languages, LabView presents an inherently more accessible, user-friendly, and troubleshooting-conducive

platform [2]. Within the LabView environment, the development of applications for device control is facilitated through the intuitive process of dragging and dropping graphical icons, circumventing the need for composing extensive lines of textual code. Each LabView function is visually represented by distinct icons and thoughtfully categorized within menus, grouping functions with similar purposes, thus streamlining the search process for specific functionalities. In addition, LabView currently integrates many applications in different fields such as: Automatic control, Digital signal processing, Real-time control, Robotics,...[3]

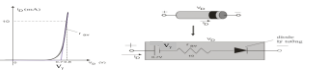
2. Research results

2.1. Diode components

a. About diode components

The diode stands as one of the foremost and widely utilized two-layer semiconductor components in electronics. A diode comprises two essential terminals, namely the anode and cathode. Current conduction through the diode exclusively transpires from the anode to the cathode under forward-biased conditions. Forward-biasing entails the configuration wherein the anode is electrically connected to a positive voltage source, while the cathode is connected to a negative voltage source.

The pivotal relationship between the voltage and current characteristics of a diode is encapsulated by a fundamental equation governing the flow of current through the P-N junction [4]:

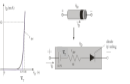


(1)

where

I_s: saturation current.

η: material factor, $1 \le \eta \le 2$

V_T: thermal voltage, 

T_K: temperature in Kelvin, $T_K = T_C + 273$

q: charge of electron, $q = 1{,}6 \times 10^{-19}$ C

k: Boltzman constant, $k = 1{,}38 \times 10^{-23}$ J/^{0}K

Characteristics V-I of formula (1):

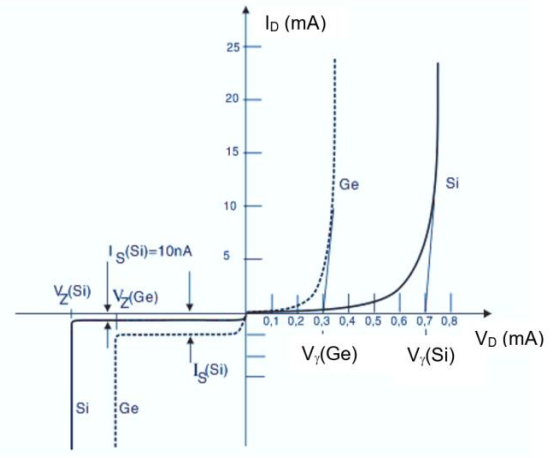


Figure 1. V-I Characteristics of Ge and Si diode [5]

Depending on the material that makes the diode, we can draw different curves. With a silicon diode, the open voltage on the curve is 0.6-0.7V (then the material factor depends on the material η = 2). If a diode is made of germanium, the opening voltage is 0.2-0.3V (η = 1).

b. Characteristics V-I of the diode are drawn by using LabView software

This is a block diagram of the program to draw the characteristic of diode.

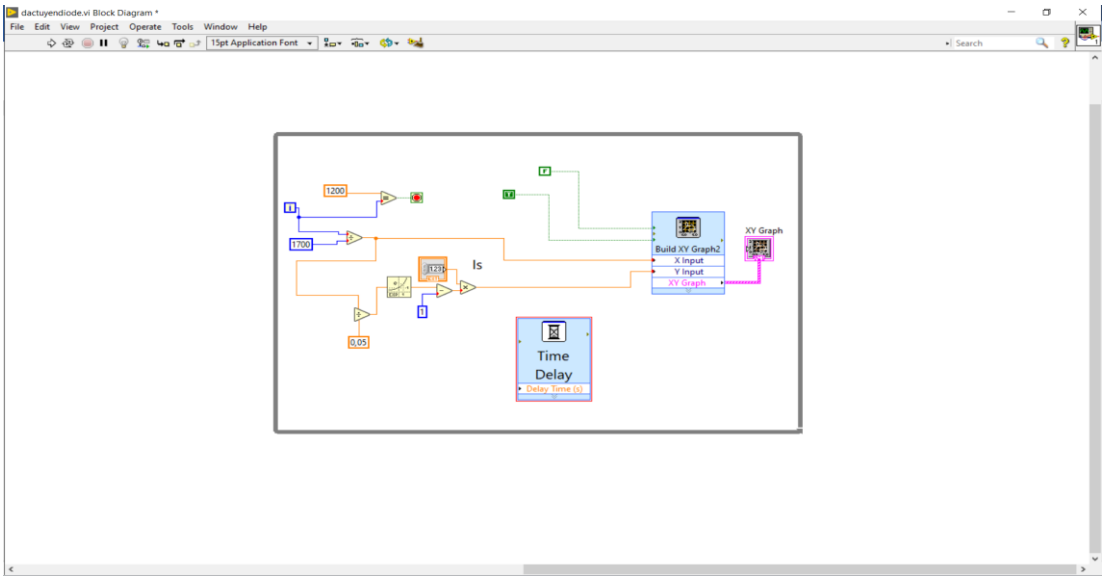


Figure 2. The block diagram of the program

When I_S=10uA, with Si diode (η = 2), we estimate the V-I characteristic by using LabView software [2]:

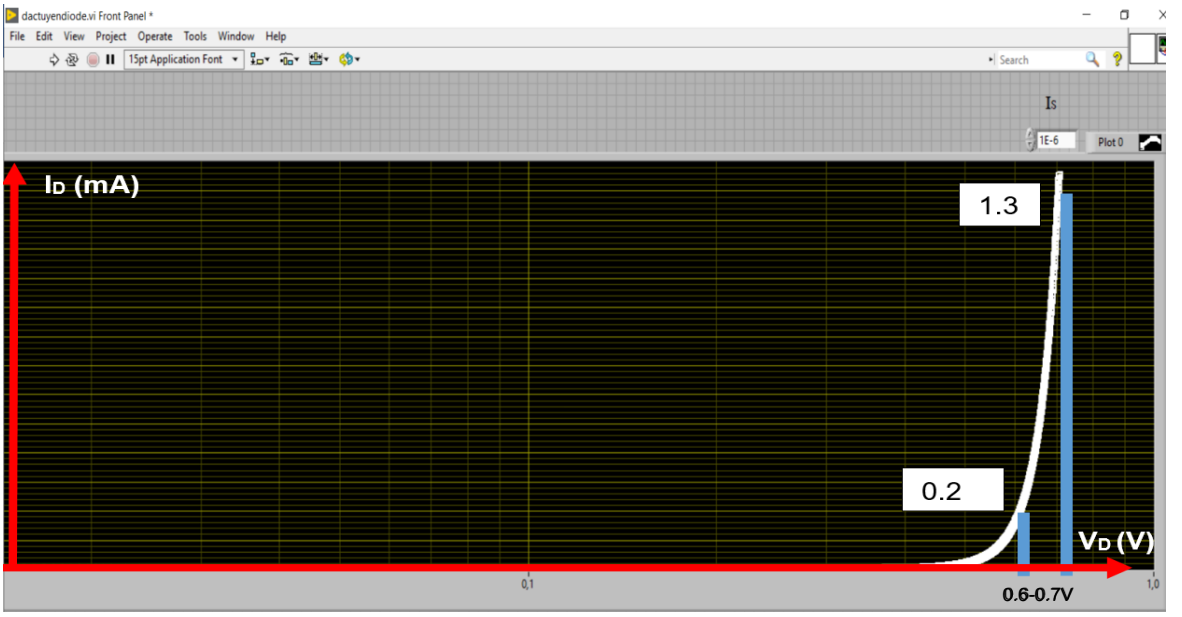


Figure 3. V-I Characteristics of Si diode

The horizontal axis of the graph represents the gradual increase in voltage between the two terminals of a two-layer semiconductor component, from 0 to 1 Volt. The vertical axis of the graph represents the increasing current through the two-layer semiconductor component.

We draw 2 straight lines to determine the open voltage, which is about 0.6-0.7V. It should be noted that the horizontal (voltage) divisions are non-linear.

From formula (1), we calculate the values of Vd and Id for the diode by cursor mode of LabView.

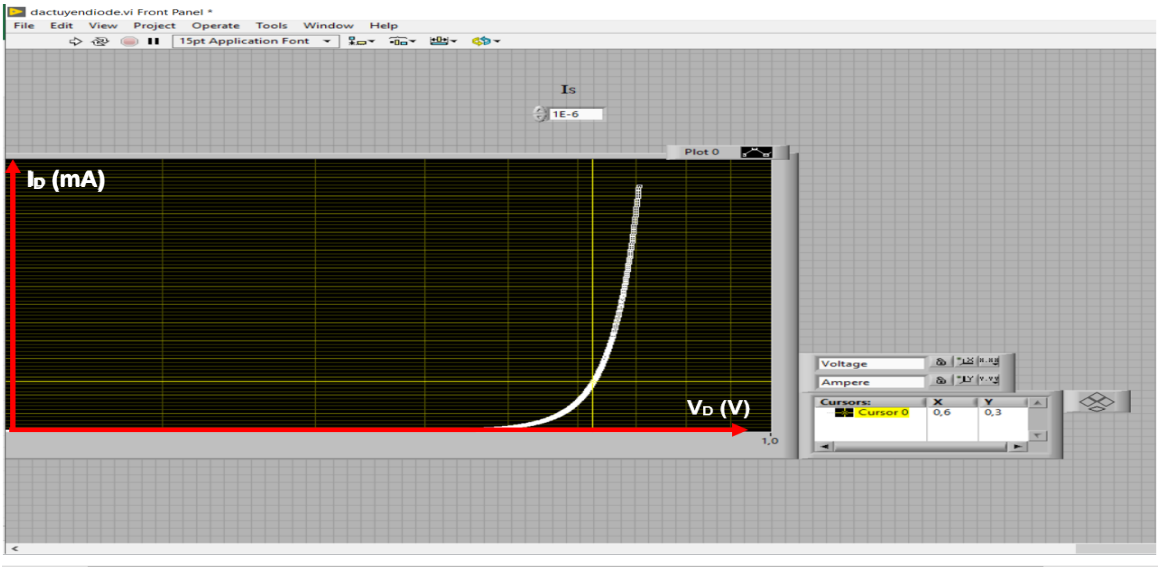


Figure 4. Cursor mode of LabView

Then, use Excel to plot the graph and curve fitting methods to find the curve of the exponential function graph.

Table 1. The values of V_D and I_D

V_D	I_D
0.6V	0.2mA
0.625V	0.3mA
0.65V	0.5mA
0.7V	1.3 mA

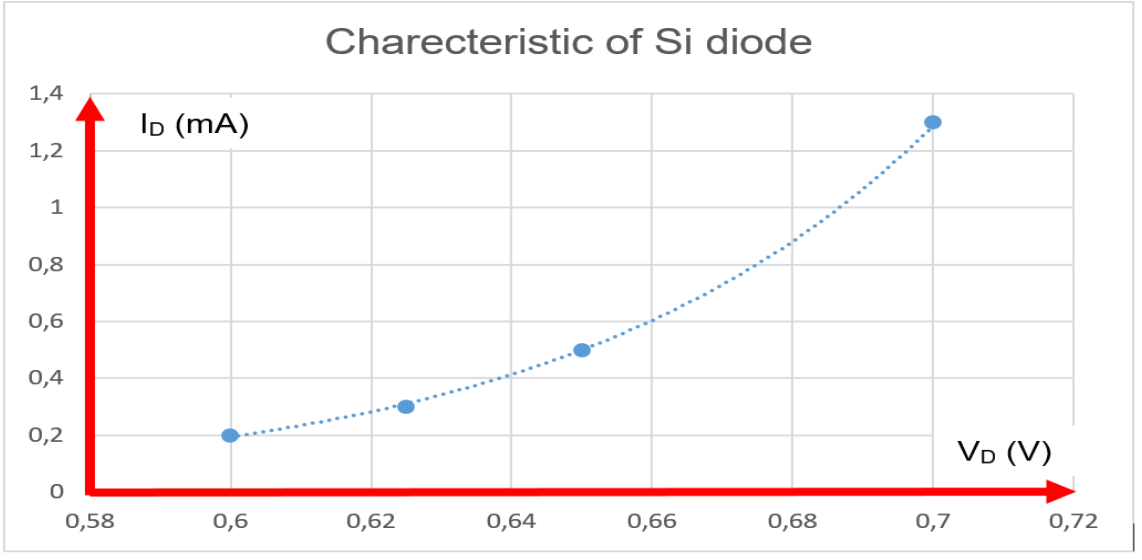


Figure 5. Drawing V-I Characteristics of Si diode with Excel

These coordinates (V_D, I_D) are utilized in Excel using the curve fitting method to determine the open voltage.

Similarly, with Ge diode ($\eta = 1$), I_S=15 uA, we have the V-I characteristic as displayed in Figure 6. The open voltage is 0.2V-0.3V.

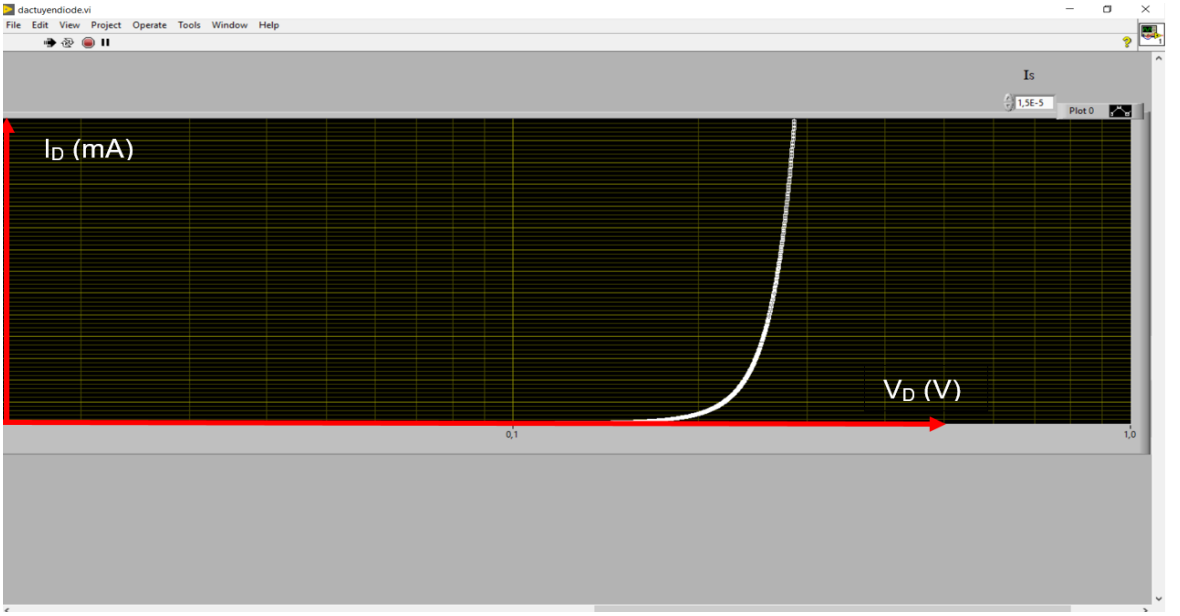


Figure 6. The V-I characteristic of Ge diode

2.2. LED components

Light Emitting Diode is called LED. This is a component with the structure of a P-N junction like a conventional diode. The special thing is that when forward-biased, the LED will emit light. Depending on the construction material, LED will have light emitted with different colors. LEDs are usually square or round. The larger the size, the larger the current through it, and the larger the consumption power.

From [6], [7], we have a data table for LEDs:

Table 2. Data table for LEDs with different colors

Wavelength (range)- nm	Color	Voltage drop	Semiconductor Material
<400	Utra Violet/ Tia cực tím	3.1-4.4 V	Aluminium nitride (AlN)/ AlGaN
400-450	Violet/Tím	2.8-4 V	Indium gallium nitride (InGaN)
450-500	Blue/Xanh dương	2.5-3.7	(InGaN)/ Silicon Carbide (SiCa)
500-570	Green/Xanh lá	1.9-4	Gallium Phosphide (GaP)
570-590	Yellow/Vàng	2.1-2.2	Gallium Arsenide Phosphide (GaAsP)

Wavelength (range)- nm	Color	Voltage drop	Semiconductor Material
590-610	Orange/amber/ Cam	2-2.2	(GaAsP)/Aluminium Gallium Indium Phosphide (AlGaInP)/ Galium Phosphide (GaP)
610-760	Red/Đỏ	1.6-2.0	AlGaAs/GaAsP/ AlGaInP/GaP
>760	Infrared/Hồng ngoại	<1.9	GaAs

The V-I characteristic of LED is similar to a diode with variety of η.

3. Conclusion

The article presented drawing V-I characteristics of diodes using LabView software. From the characteristic plots, we understand the operating principles and determine the open voltage of the components. Compared to the theory of learning curves, the difference is that the horizontal axis, which represents the voltage at the two terminals of the component, does not have an even scale. Simulation software has helped us better understand how to draw and to create V-I curves. Drawing the V-I characteristics of diodes and transistors requires delving into the current expressions of the applied voltage across the components. This endeavor deeply enhances the understanding of the operating principles of the components and allows for the creation of graphs. In doing so, one not only comprehends the shape of the characteristics curve but also gains the ability to adjust the coefficients within the expressions that describe the characteristics based on the actual materials involved. We can extend this curve for drawing characteristics of transistors (BJT, JFET, MOSFET).

Using LabView software with graphical programming language, is comfortable and effective for students and researchers. Before, drawing the characteristics of diodes, transistors used more complex code programming language.

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