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Scientific explanation of e^+ and Weyl fermion for injecting semiconductor devices

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The scientific explanation of utilizing the positron and Weyl fermion in semiconductors is presented. In view of the slow e^+ beam-generation development for imaging technology alongside the Weyl fermion which carries charge like an electron, but has no mass, thus moves much faster, injecting semiconductor devices is addressed. The information gained from this prediction has allowed the broadening of its implementation to semiconductor technology with electronic excitation using *sources other than* e^- . Developing the positron microbeam and Weyl fermions can be described with the concept of **type I** positron beam source is an alternative source of electron beam, thus harnessing the generation of γ -ray radiations inside the semiconductor heterostructures with indicating e^+ and e^- interaction with materials are different and **type II** Weyl fermions. Thus, the properties of positrons and Weyl fermion are considered suitable for carrier transport in optoelectronics. Perspectives of the development of alternative beam source for super-transport are provided.

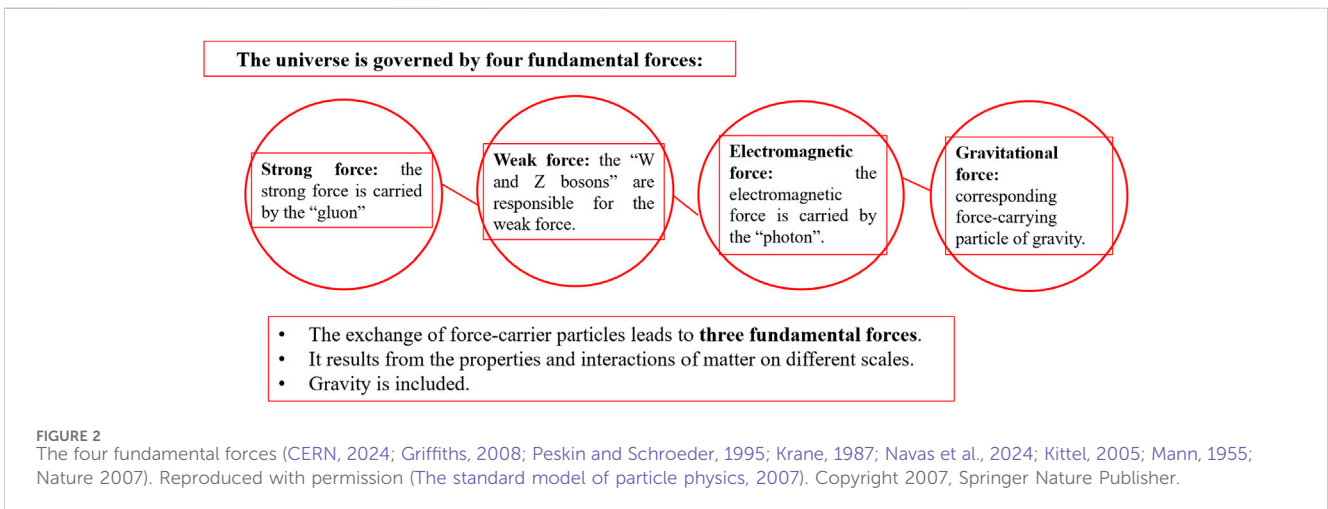
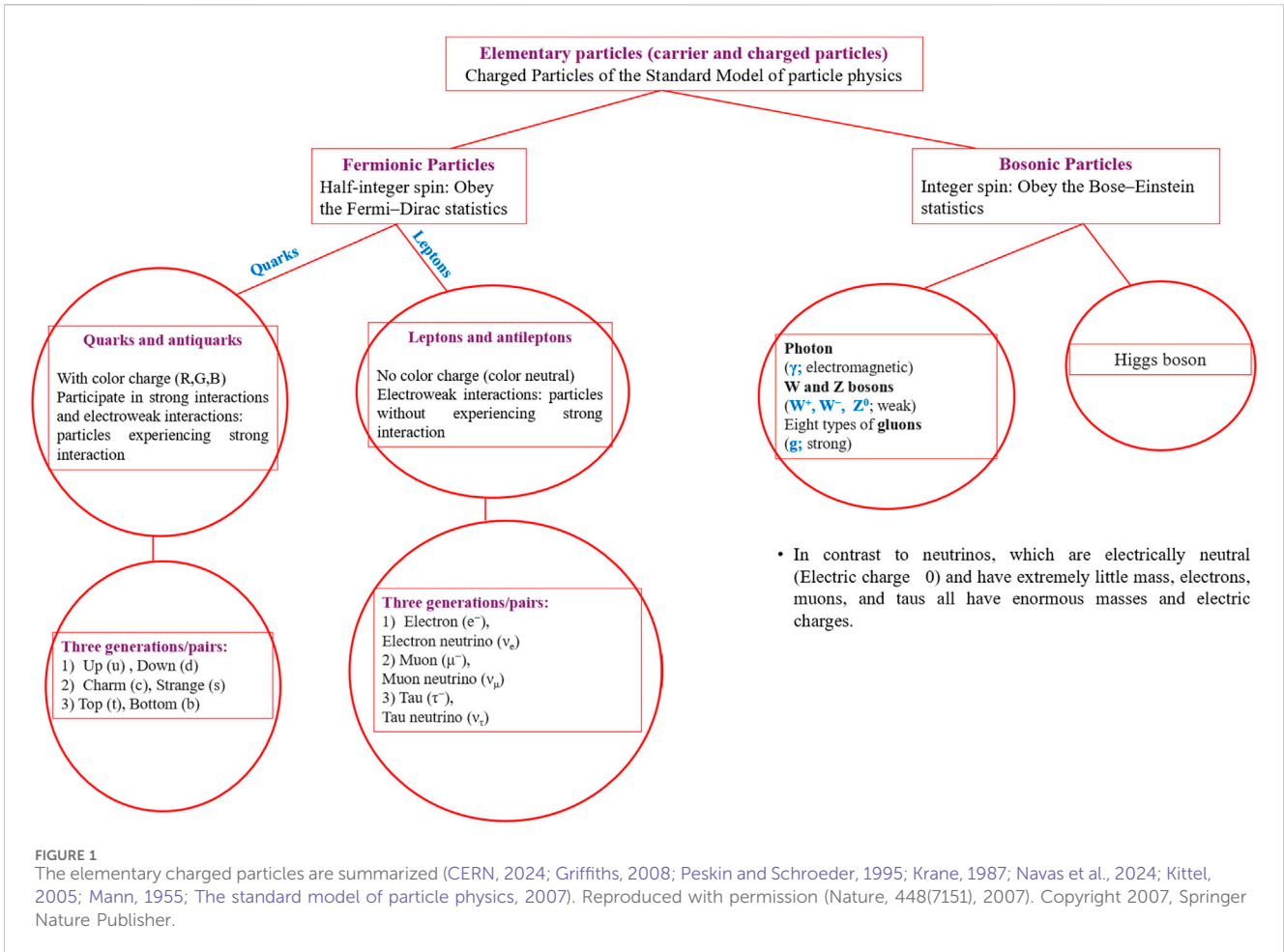
KEYWORDS

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1 Introduction

Investigating the use of alternative particles for injection into semiconductors offers an exciting opportunity to explore new areas of physics. Various types of e^- microscopes, including scanning tunneling, and field-emission microscopes, have been employed in a wide range of imaging applications. Notably, Van House et al. introduced the initial findings using positrons (e^+) as the imaging particles in a transmission microscope (Van House and Rich, 1988). Furthermore, several microscopes utilizing other particles, such as various types of ions and neutrons, have also been developed (Levi-Setti et al., 1985; Levi-Setti, 1980; Herrmann et al., 1985). Broadening the use of e^+/e^- not only as imaging particles but also as transport carriers in semiconductors. Furthermore, Weyl fermions, being massless particles, is promising due to their capability to move at extraordinary velocities (Xu et al., 2015). For the next-generation opto-electronics, this development could facilitate the seamless and highly efficient transport of electricity, significantly enhancing power delivery and performance capabilities with regarding the implanting of e^+ charged particles and Weyl fermion.

Bosons and fermions are the two classes into which elementary charged particles fall, as shown in Figure 1. Both their inherent characteristics and the statistics that follow form the basis of this classification. Fermions are half integer spin particles (e.g., $1/2\hbar$, $3/2\hbar$). Fermions are electrons, protons, neutrons, and quarks. When there are many bosons



that can occupy the identical quantum state and condense in a single quantum state, the bosonic particles are integer spin particles (e.g., \hbar , $2\hbar$) that obey Bose-Einstein statistics rather than the Pauli exclusion principle. Force-carrier particles are exchanged, giving rise to three fundamental forces. Differential amounts of energy are transferred between matter particles by means of boson exchange. (CERN, 2024; Griffiths, 2008; Peskin and Schroeder, 1995). It has been discovered

that the fundamental particles, which make up the entirety of the universe, are subject to four fundamental forces as shown in Figure 2.

Additionally, the electrons are considered slow since the optoelectronics are small. Frequent bumping, scattering, and heating occur among the transport of electrons; thus, Weyl fermions based on optoelectronics have many benefits.

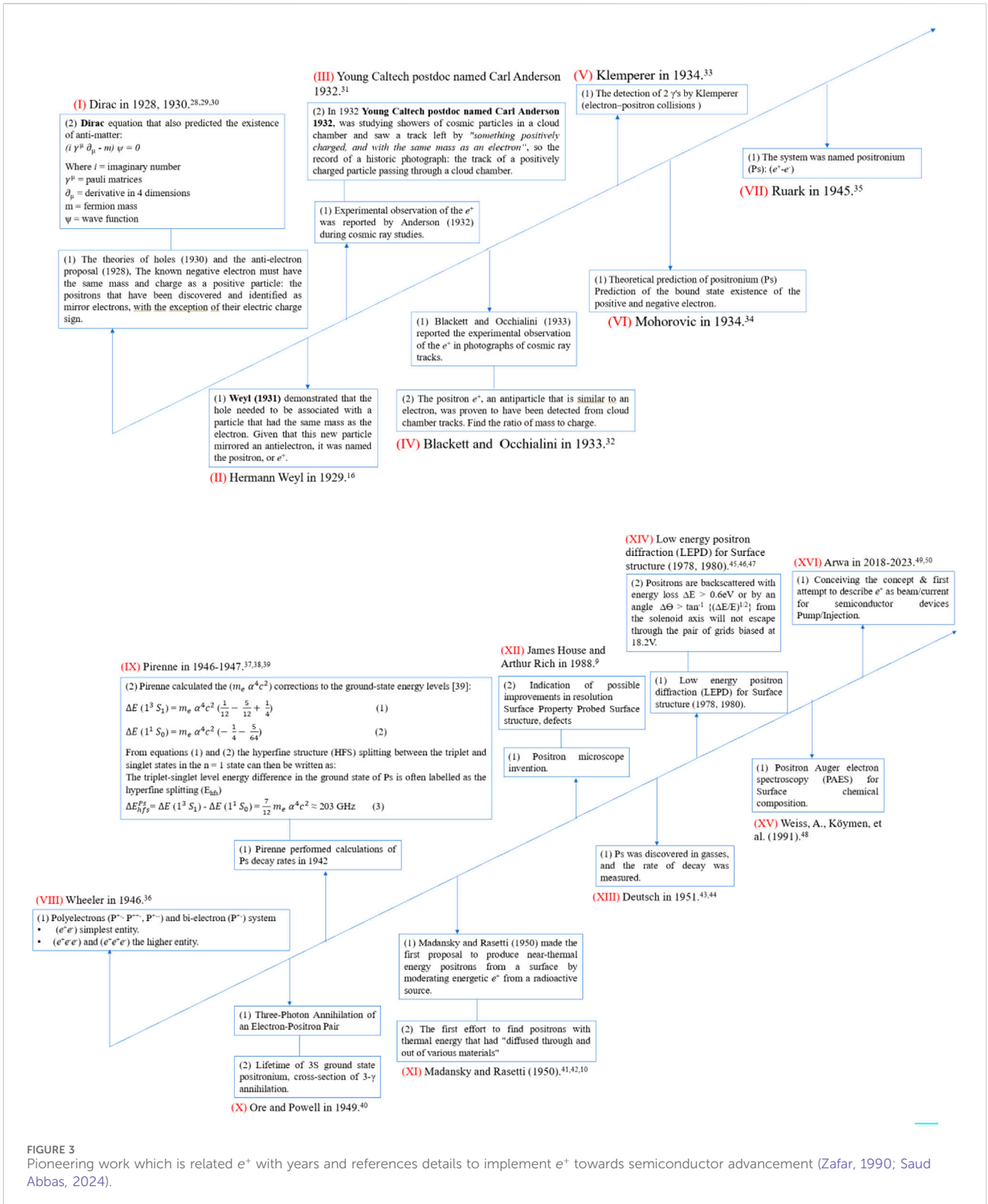


FIGURE 3 Pioneering work which is related e^+ with years and references details to implement e^+ towards semiconductor advancement (Zafar, 1990; Saud Abbas, 2024).

The current study examines alternative beam sources other than the conventional transport of electrons or optical types, such as antimatter and positron beam implementation, along with methods for producing electricity based on Weyl fermions. Introducing the positron and Weyl fermions' interaction with

the semiconductor is crucial in optoelectronics, which work by the movement of charge carriers between atoms. In Figure 3. Scientist's work related to e^+ in connection to some major progress in e^+ physics (Zafar, 1990; Saud Abbas, 2024).

TABLE 1 The electrons and positrons have distinct characteristics and energy forms (Navas et al., 2024; Ahmed, 2015; Bertozzi, 1964; Elert, 1998-2024; Santhanam, 2018; Libretexts, 2024).

Electron	Positron
(1) Rest Mass Energy	
1) The rest mass energy of an electron is given by $E=mc^2$, where m is the mass of the electron (approximately 9.109×10^{-31} kilograms) and c is the speed of light (approximately 3×10^8 meters per second). This results in a rest mass energy of approximately 0.511 MeV (million electron volts)	1) Positrons have the same mass as electrons, so their rest mass energy is also approximately 0.511 MeV
(2) Kinetic Energy	
2) The kinetic energy of an electron is determined by its velocity. For non-relativistic speeds, it is given by $KE= 1/2mv^2$. For relativistic speeds, the total energy is $E= \gamma mc^2$, where γ is the Lorentz factor	2) Like electrons, the kinetic energy of positrons depends on their velocity and can be described by the same formulas for non-relativistic and relativistic speeds
(3) Binding Energy	
3) Electrons in atoms are bound to the nucleus by electromagnetic forces. The energy required to remove an electron from an atom is called the binding energy, which varies depending on the atom and the electron's orbital	3) When a positron encounters an electron, they can annihilate each other, converting their mass into energy. This process typically produces two gamma-ray photons with an energy of 0.511 MeV each, corresponding to the rest mass energy of the electron and positron
(4) Potential Energy	
4) In a field, such as an electric or magnetic field, electrons have potential energy. For example, in an electric field, the potential energy is $U=qV$ where q is the charge of the electron and V is the electric potential	4) Positrons also experience potential energy in fields. For instance, in an electric field, the potential energy for a positron is also $U=qV$, where q is the charge of the positron (which is positive and equal in magnitude to the electron's charge)

TABLE 2 The distinguishable features of positrons and holes (Navas et al., 2024; Kittel, 2005; Ahmed, 2015; Alvarez, 2013; Hemenway et al., 1967; Cross, 1978).

	Positrons	Holes
1) Nature and Origin:	Antiparticle: Positrons are the antiparticles of electrons Existence: They exist naturally in processes like beta plus decay in radioactive decay and are produced in particle accelerators and cosmic ray interactions	Quasi-Particle: Holes are not particles in the traditional sense; they represent the absence of an electron in a semiconductor's valence band. Existence: Holes exist in solid-state physics, specifically in the context of semiconductor materials
2) Charge and Mass:	Charge: Positrons carry a positive charge of $+1e$ Mass: They have the same mass as electrons	Charge: Holes effectively carry a positive charge of $+1e$ Effective Mass: The effective mass of a hole depends on the material and the band structure of the semiconductor; it is often treated as different from the mass of an electron
3) Interaction with Matter:	Annihilation: When a positron encounters an electron, they annihilate each other, producing gamma rays Behavior in Magnetic and Electric Fields: Positrons behave similarly to electrons but move in the opposite direction in an electric field due to their positive charge	Recombination: Holes can recombine with electrons, resulting in the emission of energy, typically in the form of photons Behavior in Magnetic and Electric Fields: Holes contribute to electrical conduction in semiconductors by moving in the direction of the applied electric field, opposite to the electron movement

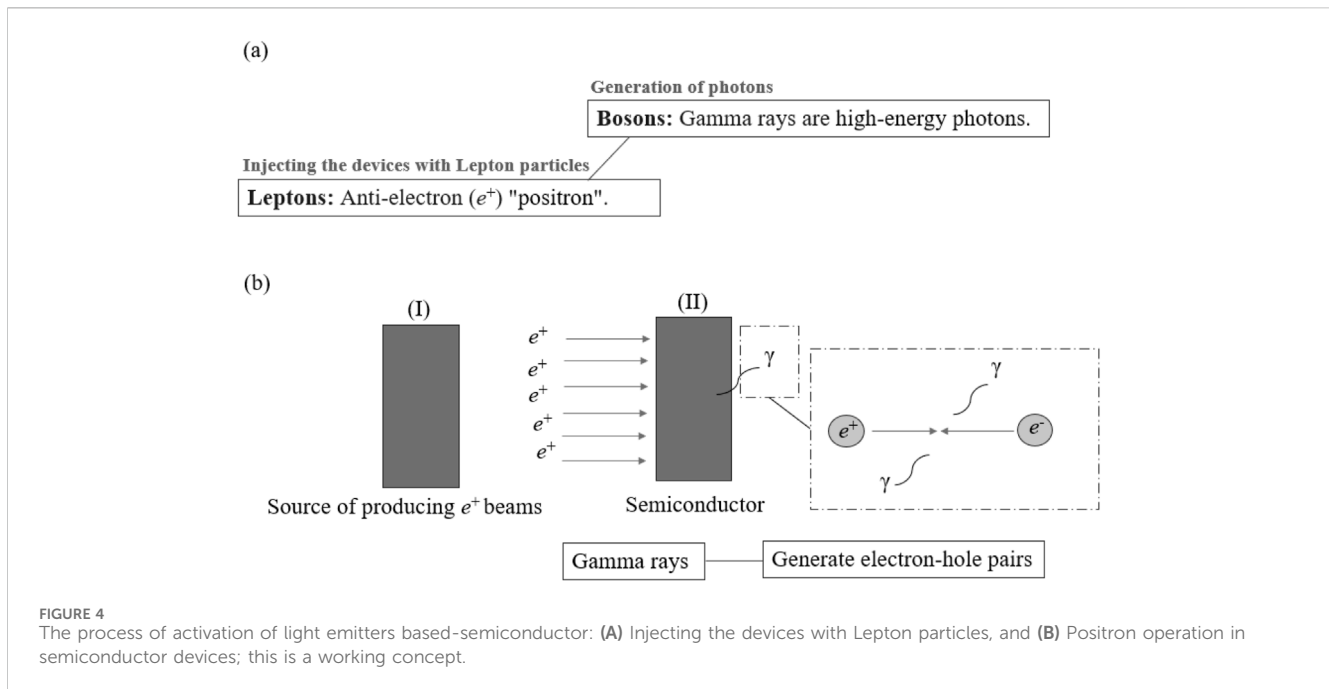
2 Electron and positron energy forms and distinguishable features of positrons and holes

2.1 Electrons and positrons

Fundamental particles categorized as leptons include electrons, which have a negative electric charge. The opposite of an electron is a positron. They are *positively* charged but have the same mass as electrons. Positrons are fermions and are similar to electrons in their quantum characteristics. However, *gamma-ray photons* can be produced when an electron and a positron collide and annihilate one another. The subatomic particles known as electrons and positrons have distinct characteristics and energy forms. A brief description of each is provided in Table 1.

2.2 Positrons and holes

Although both particles—positrons and holes—carry positive charge, their origins and characteristics differ. These are the qualities that set them apart, as shown in Table 2. Positrons are real particles with a positive charge. They have equal mass to electrons, and they originate from particle interactions and decay processes. Positrons annihilate with electrons and are used as medical imaging or semiconductors defect investigations. Holes are quasi-particles representing the absence of electrons in semiconductors, and they have an effective positive charge and mass depending on the material. Holes are vital for the function of semiconductor devices (Griffiths, 2008; Krane, 1987; Navas et al., 2024; Kittel, 2005).



3 Working concept of positron in semiconductor devices

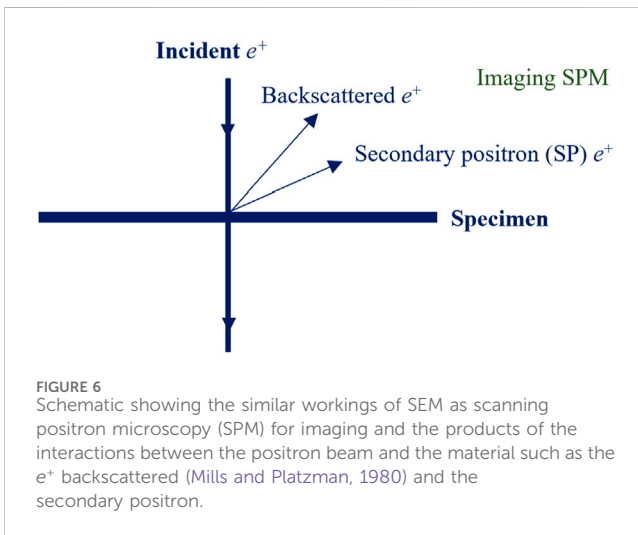
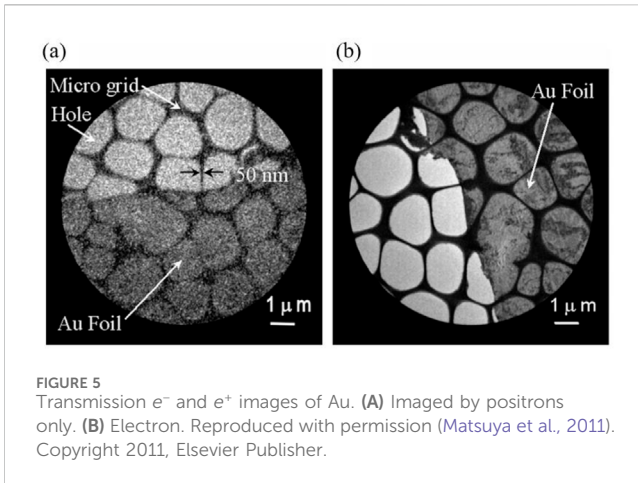
First, the antiparticle of electrons, known as positrons, is primarily employed in semiconductor devices for defect analysis using a method known as positron annihilation spectroscopy (PAS). Utilizing the special interactions between positrons and the electrical structure of the material, PAS offers insightful data regarding the defects present in the semiconductor (Krause-Rehberg and Leipner, 1999; Coleman, 2000). Second, positron sources are not realized for the majority of semiconductor carrier injection's practical applications. An overview of the literature reveals that the primary practical uses of semiconductor carrier injection do not involve the utilization of positron sources or any other sources, such as Weyl fermions. Contributions to the flow of e^+ could solve this problem. As shown in Figure 4, the process of activation of light emitters based-semiconductor involves (a) Injecting the devices with Lepton particles, and (b) Positron operation in semiconductor devices. This is a working concept for the generation of photons in semiconductors using other sources than e^- .

3.1 e^+ beam source

The sodium-22 source, which emits β^+ , is the radioactive source (Van House and Rich, 1988) used to produce the positron beam in Figure 4. The positrons from this decay have a high energy of approximately 300 keV and have the potential to produce a slowing beam. James House et al. observed the interaction between approximately 2 eV e^+ beam and the near-surface region of a solid, reporting e^+ as the imaging particle (Van House and Rich, 1988). During this procedure, the high-energy (~ 100 – 500 keV) source e^+ thermalized in a crystal, such as a W crystal, and was expelled at an energy value of approximately 2 eV with a probability

of 10^{-3} – 10^{-4} . A beam is then created as a result of the ejected e^+ . The existence of the positron, the electron's antimatter counterpart, has prompted a great deal of research into its behavior, especially in this recently-developed area of study on the properties of its interactions with a semiconductor. A positron beam source can be used in place of the electron emitter in a new generation of energetic source-driven semiconductor devices, which is their principal advantage. Mesons are often composed of a quark and an antiquark, while *positronium* is typically composed of an electron and a positron, and for the positron can be inelastically, or elastically backscattered towards annihilation or to be free positronium (Mills and Platzman, 1980). The positron and electron have similar masses and spins, but the positron's charge has the opposite sign even if its magnitude is the same. Wide energy distribution positron sources up to high energies [keV–MeV] (Zafar, 1990) have been proposed for pumping and injecting semiconductor-based emitters based on a (Al,Ga)N material system. However, taking into account the evaluation of specific electron beam delivery must fall within the accepted range of eV values in order to prevent any damage that could result from the influence of e^-/e^+ beam irradiation on optical or electrical properties.

As the electron's antimatter counterpart is readily accessible, there have been numerous studies conducted on the behavior of positrons as well as their production and application. The two techniques used to generate and use the positron beam emission—the laser-based source for electron and positron creation and the slow/fast positron beam technique—are essential to comprehending the behavior of the positron. As "slow positron moderators," several materials are employed, such as thin single-crystal Ni(100) and W(100) foils. The radioactive sources producing the rapid positrons have mean energies varying from several hundred keV to MeV (Zafar, 1990). Positron beam energy is comparable to electron beam energy. The starting point for the creation of positron beams is a sodium-22 source that emits β^+ . To regulate the positrons for use in further research, they must first be



slowed down due to their high energy (300 keV) that results from their decay. The first findings were acquired using a transmission microscope equipped with the positron imaging particle. Similar to how electrons interact with matter, positrons' interactions can reveal information about basic processes (Jmerik et al., 2023). The e^+ generating radioactive source's brightness, which is originally not high for imaging, can be increased by the process of moderation, which also boosts the instrument's success (Mills et al., 1983; Schultz and Lynn, 1988). Heterostructure device development is based on the positron beam produced by a light emitter converting into positrons or the other potential process to convert an electron into a positron (Rosen, 2015).

3.2 The positron beam's interactions with materials

In Figure 5, there is an obvious distinction between the electron and e^+ images (Matsuya et al., 2011; Autjors Anonymous, 1924). To clarify the difference in imaging between e^- and e^+ , e^+ imaging process should be a similar working concept to e^- as shown in Figure 6.

For the *imaging* principle:

- When the main e^- in a scanning electron microscope (SEM) is targeted onto the material surface, various particles and waves are emitted, including photons, Auger e^- , back-scattered e^- , X-rays, secondary e^- , etc.
- The *imaging* uses backscattered and secondary electrons, while the X-rays provide chemical details about the emitting atoms.
- Because the electron beam travels in a vertical direction via the microscope's column, additional electrons are ejected from the sample as it comes into contact with it. The secondary or backscattered electrons are gathered by the detectors, which then transform them into a signal and send it to a viewing screen that resembles a regular television to produce a picture.

Rohrlich and Carlson et al. have demonstrated that, when using a transmission positron microscope (TPM), positron cross-sections could be greater than electron cross-sections. That indicates e^+ with a certain energy range, a small scattering angle corresponds to a large scattering intensity. (Rohrlich and Carlson, 1954). Ultimately, significant variations between the e^- and e^+ diffraction contrast are predicted to transpire at energies of up to 1 MeV. (Ramamoorthy and Haji-Saeid, 2004; Hulett et al., 1984).

4 Massless particle for carrier transport in semiconductors

Weyl fermions are massless, highly mobile, and exhibit both matter-like and anti-matter behavior, in contrast to electrons (Kelly, 2015). The distinct characteristics of Weyl fermions, first proposed in 1929, may play a role in the development of quantum computers and rapid electrical circuits (Weyl, 1929). Hermann Weyl discovered an additional solution to the Dirac equation which involved massless particles (Wang et al., 2017). Due to their fundamental characteristics, Weyl fermions travel rapidly on the crystal surface without backscattering, which in typical electronic materials increases heat rate and decreases efficiency. There are numerous benefits to using electronics with Weyl fermions. This is due to the requirement that an electron without mass move at the speed of light. Due to some spin features that are difficult to explain at this level, their transfer is faster and avoids colliding with objects. The distinct features of Weyl fermions are as follows:

- 1) Chirality: In terms of spin and motion direction, Weyl fermions are classified as left- or right-handed.
- 2) Massless: Weyl fermions are potentially massless in contrast to electrons and positrons.
- 3) Topology: Quasiparticles in some materials can exhibit Weyl fermionic behavior, giving rise to exotic phenomena such as the Weyl semimetal phase in which the conduction and valence bands touch at discrete locations known as Weyl points.

In 2013, Ling Lu et al. suggested that Weyl points physics, which is incorporated into condensed-matter physics, may also be achieved in photonic crystals. (Lu et al., 2013). Weyl quasiparticles exhibit non-trivial topological features and obey relativistic equations of

motion, which partially protects them against scattering. Since Weyl fermions have no mass, Weyl fermions can transport electricity through a substance far more quickly than regular electrons. Faster optoelectronic devices might be created by utilizing this feature (Xu et al., 2015; Johnston, 2015; Jeffrey, 2015). The transformation to Weyl fermion is thought to transfer electric charge through a device significantly faster than that of regular electrons.

5 Conclusion and future work

In conclusion, I have taken the first attempt towards scientifically describing the utilization of the e^+ and Weyl fermion in semiconductors. In view of the rapid developments in imaging analysis and slow e^+ beam generation, there may be more opportunities to increase the use of positrons in semiconductor technology. Since this research will offer a distinct advantage for using other charged carriers instead of e^- arising from this proposal, the upcoming years could be critical for furthering this technology. In light of the e^+ and Weyl fermions' potential application in the semiconductor industry, the beam sources should be developed to improve the efficiency of electronics and opto-electronic devices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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