【外文本】

High-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonic transmission module

Abstract

This invention provides a high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module, which achieves a 50% photoelectric conversion efficiency and integrates silicon photon transmission function, providing a new opportunity for high-efficiency solar power generation and instant optical communication. Multifunctional platform. The module includes a multi-layer structure arranged from top to bottom: anti-reflection layer, transparent conductive oxide layer, perovskite absorption layer, tunnel junction layer, silicon photon absorption layer, electron and hole transport layer, silicon photon waveguide and a modulation layer, a thermoelectric material layer, a heat dissipation layer, a bottom electrode layer, a silicon photon receiver layer and a substrate layer. Quantum dots and 3D photonic crystal structures are embedded in the perovskite absorption layer to effectively improve the efficiency of photon absorption and transmission; silicon photonic waveguides and modulation layers can achieve high-speed optical signal encoding and transmission, supporting optical communication rates of 10-100 Gbps. Thermoelectric material layers and heat dissipation layers further optimize thermal management to prevent thermal degradation under high-efficiency operation, while achieving energy recovery and stable operation. The module is suitable for smart surfaces, IoT networks and autonomous systems, providing a sustainable and versatile solution to meet the efficient needs of future energy and data.

[Designated representative picture] As shown in Figure 1.

[A brief explanation of the symbols of the representative diagram]

1. Anti-reflection layer

2. Transparent conductive oxide layer
3. Perovskite absorber layer
4. Tunnel junction layer
5. Silicon Photon Absorption Layer
6. Electron transport layer
7. Hole transport layer
8. Silicon photonic waveguide and modulation layer
9. Thermoelectric material layer
10. Heat dissipation layer
11. Bottom electrode layer
12. Silicon photon receiving layer
13. Base material layer

Specification

【Technical field】

[0001] This invention relates to the field of integration of solar photovoltaic technology and optical communication technology, and in particular to the structural design of a high-efficiency, multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module. The technology aims to achieve multifunctional integration of photoelectric conversion and high-speed optical communication through the innovative structural design of the perovskite absorption layer. It is suitable for smart buildings, Internet of Things networks and other autonomous systems, providing efficient and stable energy and data solutions.

【Prior technology】

[0002] Current organic photovoltaic technology has shown high efficiency potential, but there are still limitations in photoelectric conversion efficiency and stability. In addition, silicon photonics technology has gradually matured in recent years and can support high-speed optical communications, but it has not been widely used in integration with photovoltaic technology. The present invention solves the technical challenge of integrating high-efficiency perovskite organic photovoltaic cells with silicon photonic transmission systems to achieve better light harvesting and multifunctional applications.

【Content of the invention】

[0003] This invention provides a high-efficiency, multifunctional, integrated flexible perovskite photovoltaic cell and silicon photon transmission module, the technical features of which are as follows:
Layer structure design:
The module consists of a multi-layer structure, from top to bottom, an anti-reflection layer, a transparent conductive oxide layer, a perovskite absorption layer, a tunnel junction layer, a silicon photon absorption layer, an electron and hole transport layer, and a silicon photon waveguide. and a modulation layer, a thermoelectric material layer, a heat dissipation layer, a bottom electrode layer, a silicon photon receiving layer and a substrate

layer.

Perovskite absorption layer: By embedding quantum dots and 3D photonic crystal structure, the photon absorption efficiency in the 300-800 nm band is significantly enhanced.

Silicon photonic waveguide and modulation layer: Support 10-100 Gbps high-speed optical communications and further realize the encoding and transmission of optical signals.

Thermoelectric material layer and heat dissipation layer: Provide efficient thermal management, prevent thermal degradation and recycle heat energy for electrical output, improving module stability.

Function integration:
The module combines high-efficiency solar power generation with real-time optical communication capabilities, and is suitable for applications in smart surfaces, the Internet of Things, and autonomous systems. This innovative design integrates multiple functions into a single film, providing simultaneous support for energy and data transmission.

Sustainability and flexible application:
The base material is made of flexible material, which is not only suitable for curved surface installation, but also has good portability and adaptability, meeting the diverse needs of smart buildings and mobile devices.

【Simple explanation of the diagram】

【0004】

Figure 1. Overall structure diagram
Figure 2. Cross-section of interlayer structure
Figure 3. Optical performance analysis chart
Figure 4. Thermal management system diagram
Figure 5. Schematic diagram of silicon photonic transmission function
Figure 6. System integration and application scenarios such as smart surfaces (6-1), IoT devices (6-2), smart cities (6-3) etc.

【Implementation】

[0005] Please refer to FIG. 1, FIG. 2 and FIG. 5. The invention provides a high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module 19, which is connected from top to bottom. The layer structure design effectively improves the light capture efficiency, photon transmission channel performance and thermoelectric stability. Based on the structural design of the high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module 19, the detailed technical features are as follows: The reflective layer 1 is 80-120 nm thick and is made of silicon dioxide or silicon nitride. It is arranged on the outermost layer of the high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and the silicon photon transmission module 19 to reduce Reflection loss and improve light capture efficiency, transparent conductive oxide layer 2, with a thickness of 50-100 nm, made of ZnO or ITO material, is arranged under the anti-reflection layer 1, has high light transmittance and excellent conductivity, perovskite absorption Layer 3, with a thickness of 100-500 nm, contains quantum dots with a particle size of 0.5-2 nm and a 3D photonic crystal structure, and is located below the transparent conductive oxide layer 2. It is mainly used to absorb the photon energy in the 300-800 nm band and enhance Light absorption effect, tunnel junction layer 4, with a thickness of 5-15 nm, composed of doped oxide materials, arranged below the perovskite absorption layer 3, can optimize the transmission of electrons and holes and reduce interface losses, silicon photon absorption layer 5 , with a thickness of 500 nm, is disposed below the tunnel junction layer 4 and is made of a high refractive index material for capturing photons and performing energy conversion, an electron transport layer (ETL) 6 and a hole transport layer (HTL) 7, with a thickness of 10-50 nm, close to the silicon photon absorption layer 5, composed of materials containing silver or gold, used to enhance the optical field effect and improve the carrier transmission efficiency, the silicon photon waveguide and modulation layer 8, with a thickness of 200 nm, It is arranged below the electron transport layer 6 and the hole transport layer 7, and contains a slot waveguide structure, which can support 10-100 Gbps optical communication transmission and is suitable for smart buildings and Internet of Things applications. The thermoelectric material layer 9 has a thickness of 100-300 nm, arranged below the silicon photonic waveguide

and modulation layer 8, made of bismuth telluride or bismuth selenide material, with thermoelectric conversion and heat dissipation functions, the heat dissipation layer 10, with a thickness of 50 nm, arranged below the thermoelectric material layer 9, The bottom electrode layer 11 is used to further dissipate heat and maintain the stability of the module operation. The bottom electrode layer 11 has a thickness of 100 nm and is arranged below the heat dissipation layer 10. It is made of metal material and is used for carrier collection and conduction. The silicon photon receiving layer 12, with a thickness of 100 nm, is arranged below the bottom electrode layer 11, and is used to receive optical signals and decode them into electrical signals. The substrate layer 13, with a thickness of 500 μm, is a high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and The substrate of the silicon photon transmission module 19 is made of a flexible material to provide overall structural support and realize the bending and portability of the module.

【Explanation of symbols】

[0006]

1. Anti-reflective layer
2. Transparent conductive oxide layer
3. Perovskite absorption layer
4. Tunnel layering
5. Silicon photon absorption layer
6. Electron Transport Layer (ETL)
7. Hole Transport Layer (HTL)
8. Silicon photonic waveguide and modulation layer
9. Thermoelectric material layer
10. Heat dissipation layer
11. Bottom electrode layer
12. Silicon photon receiving layer
13. Base material layer
14. Optical signal generation area
15. Silicon photonic waveguide
16. Modulator area
17. Signal conversion area
18. Heat dissipation and thermal power management
19. High-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonic transmission module

20. Sunshine
21. High efficiency photoelectric conversion
22. Energy storage
23. Silicon photonic transmission
24. Smart devices
25. Data monitoring
26. Wireless transmission
27. Equipment
28. Self-powered
29. The IoT base station contains high-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonics Transmission module
30. Smart traffic signs contain high-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonics Transmission module
31. IoT devices
32. Smart agricultural sensors contain high-efficiency, multi-functional integrated flexible perovskite photovoltaic cells and silicon light Sub-transmission module
33. Cloud
34. Solar energy
35. Power supply
36. Battery
37. The photovoltaic base station contains high-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonic transmission modules.

Claims

[Claim 1] A high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module, characterized by comprising the following layer structures, from top to bottom:
Anti-reflection layer: 80-120 nm thick, made of silicon dioxide or silicon nitride, located on the outermost layer of the module to reduce reflection loss and improve light capture efficiency;
Transparent conductive oxide layer: 50-100 nm thick, made of ZnO or ITO material, directly below the anti-reflection layer to achieve high light transmittance and excellent conductivity;

Perovskite absorption layer: 100-500 nm thick, containing quantum dots with a particle size of 0.5-2 nm and a 3D photonic crystal structure, set under the transparent conductive oxide layer to improve light absorption efficiency, mainly absorbing the 300-800 nm band the photon energy;

Tunnel junction layer: 5-15 nm thick, composed of doped oxides, located below the perovskite absorption layer, optimizes the transmission of electrons and holes and reduces interface losses;

Silicon photon absorption layer: 500 nm thick, located below the tunnel junction layer, made of high refractive index material, used to further capture photons and perform energy conversion;

Electron and hole transport layer: 10-50 nm thick, close to the silicon photon absorption layer, composed of silver or gold-containing materials, used to enhance the optical field effect and improve the carrier transport efficiency;

Silicon photonic waveguide and modulation layer: 200 nm thick, located below the electron and hole transport layers, with a slot waveguide structure, supporting 10-100 Gbps optical communication transmission, suitable for smart buildings and IoT applications;

Thermoelectric material layer: 100-300 nm thick, located below the silicon photonic waveguide and modulation layer, made of bismuth telluride or

bismuth selenide material, with thermoelectric conversion and heat dissipation functions;

Heat dissipation layer: 50 nm thick, located below the thermoelectric material layer, used to further dissipate heat and maintain module stability;

Bottom electrode layer: 100 nm thick, located below the heat dissipation layer, made of metal material, to achieve carrier collection and conduction;

Silicon photon receiver layer: 100 nm thick, located between the bottom electrode layer and the substrate layer, used to receive and optimize photon signals;

Substrate layer: 500 μm thick, serving as the base of the module, providing overall structural support, and using flexible materials to achieve bending and portability.

[Claim 2] High-efficiency multi-functional integrated flexible perovskite photovoltaic cells and silicon photonic transmission modules as described in Claim 1, suitable for smart buildings, smart agriculture, electric vehicle roofs, military security facilities, space equipment, etc. Multifunctional smart applications provide instant energy supply and data transmission to meet the needs of low-power Internet of Things and remote monitoring.

[Claim 3] High-efficiency multi-functional integrated flexible perovskite photovoltaic cell and silicon photonic transmission module as described in Claim 1:
One of the methods for preparing quantum dots includes synthesizing perovskite quantum dots using a solution method or vapor deposition method, and surface modification to improve stability and photoelectric properties; the advantage of this method is that it can be produced at low cost and on a large scale Maintain high uniformity and controllability in production.
The method of introducing defects is to use photolithography technology or etching technology to introduce specific defect sites inside the photonic crystal, and adjust the position and size of the defects to optimize the resonance characteristics of light and improve the photoelectric conversion efficiency.

[Claim 4] As described in Claim Item 1, the control algorithm of the dynamic energy management system of the high-efficiency multi-functional integrated flexible perovskite photovoltaic cell and silicon photonic transmission module has advantages over traditional algorithms and can achieve higher Excellent energy utilization efficiency and faster response speed; the system can automatically adjust energy output according to real-time light intensity and load requirements to minimize energy loss.

[Claim 5] An integral photovoltaic thin film high-efficiency multi-functional integrated flexible perovskite photovoltaic cell and silicon photon transmission module as described in Claim 1, which is characterized by:
Consists of a support layer consisting of a selected flexible substrate with high mechanical stability and environmental resistance;
The interface bond between each layer of film is formed through a specific low-temperature deposition technology, which ensures that each layer has good adhesion and high photoelectric conversion performance;
The thickness and material properties of each layer of film are optimally arranged to improve the stability and durability of the module, and meet the needs of smart buildings, the Internet of Things and other multi-functional applications.

[Claim 6] The high-efficiency multifunctional integrated flexible perovskite photovoltaic cell and silicon photon transmission module as described in Claim 1, wherein the silicon photon transmission module is characterized by:
Waveguide structure design: The module contains a silicon photonic waveguide layer with a width of 200nm, which supports multi-modal optical transmission through a slit waveguide structure while achieving a data transmission rate of 10-100 Gbps;
Optical signal coupling and decoupling: Optical couplers and decouplers are provided at both ends of the waveguide layer to efficiently couple the optical signal from the external light source into the waveguide and decouple it at the terminal; the coupler is selected Made of graded refractive index materials to reduce light loss caused by mode mismatch;
The low-loss transmission material comprises a silicon photonic waveguide layer fabricated from high-purity silicon with low absorption

and low scattering; A protective layer, typically 10-50 nm thick, made of silicon nitride or aluminum oxynitride, is deposited on the surface to enhance transmission stability and resistance to environmental disturbances.

Integration of data processing and photoelectric conversion: When the silicon photonic waveguide layer is integrated with the perovskite photovoltaic cell, the optical coupling layer (tunnel junction layer) is used for vertical light transmission; during the transmission process, the silicon photonic module can convert the optical signal into Convert to electrical signals to achieve integrated photoelectric processing, suitable for high-speed data transmission in smart buildings and Internet of Things scenarios;

Multi-functional application support: the module supports signal transmission within a multi-spectral range and can dynamically adjust the transmission rate and bandwidth according to application requirements, making it suitable for multi-scenario applications such as smart agriculture, remote monitoring and high-performance computing.

Figures

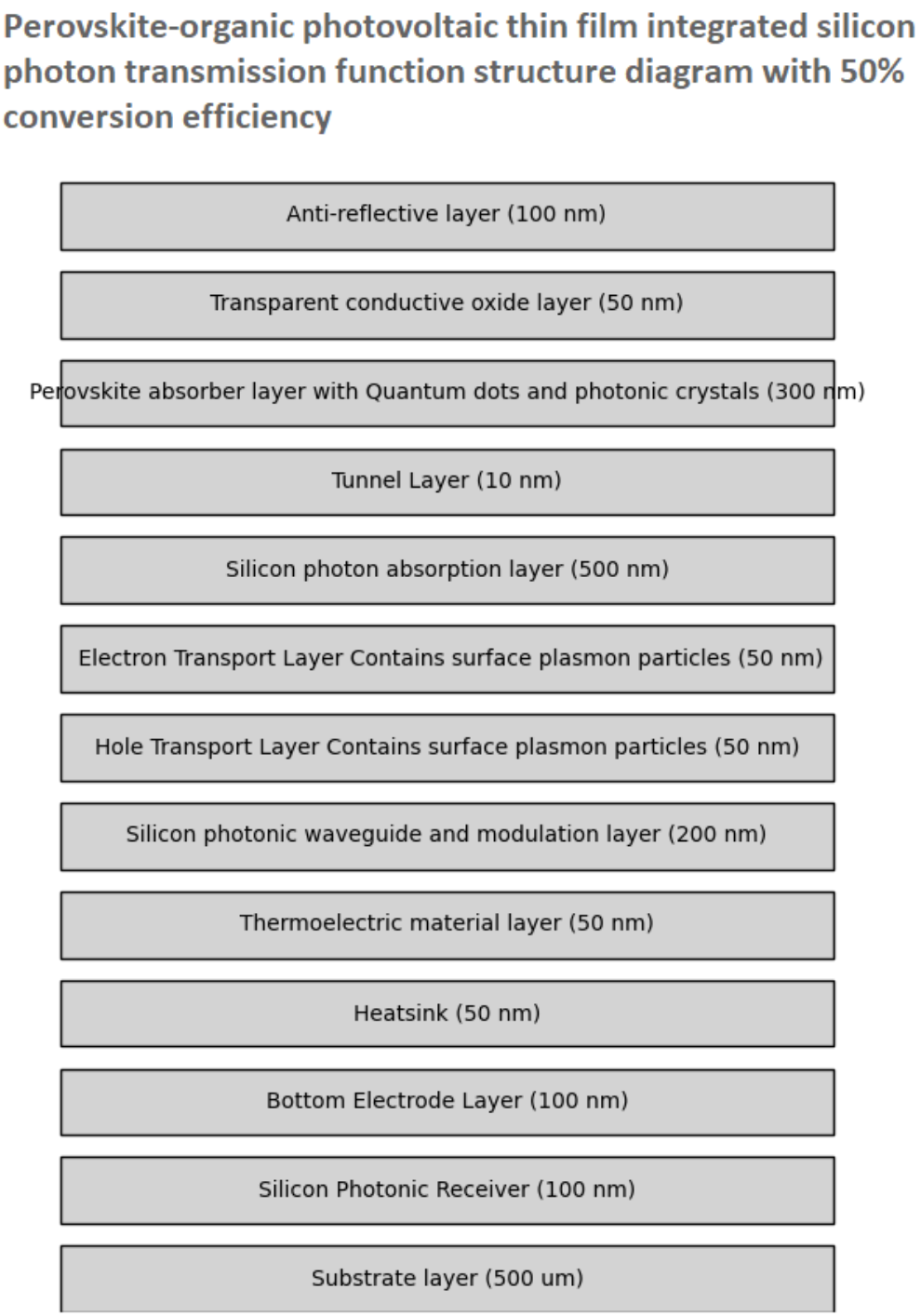

Figure 1

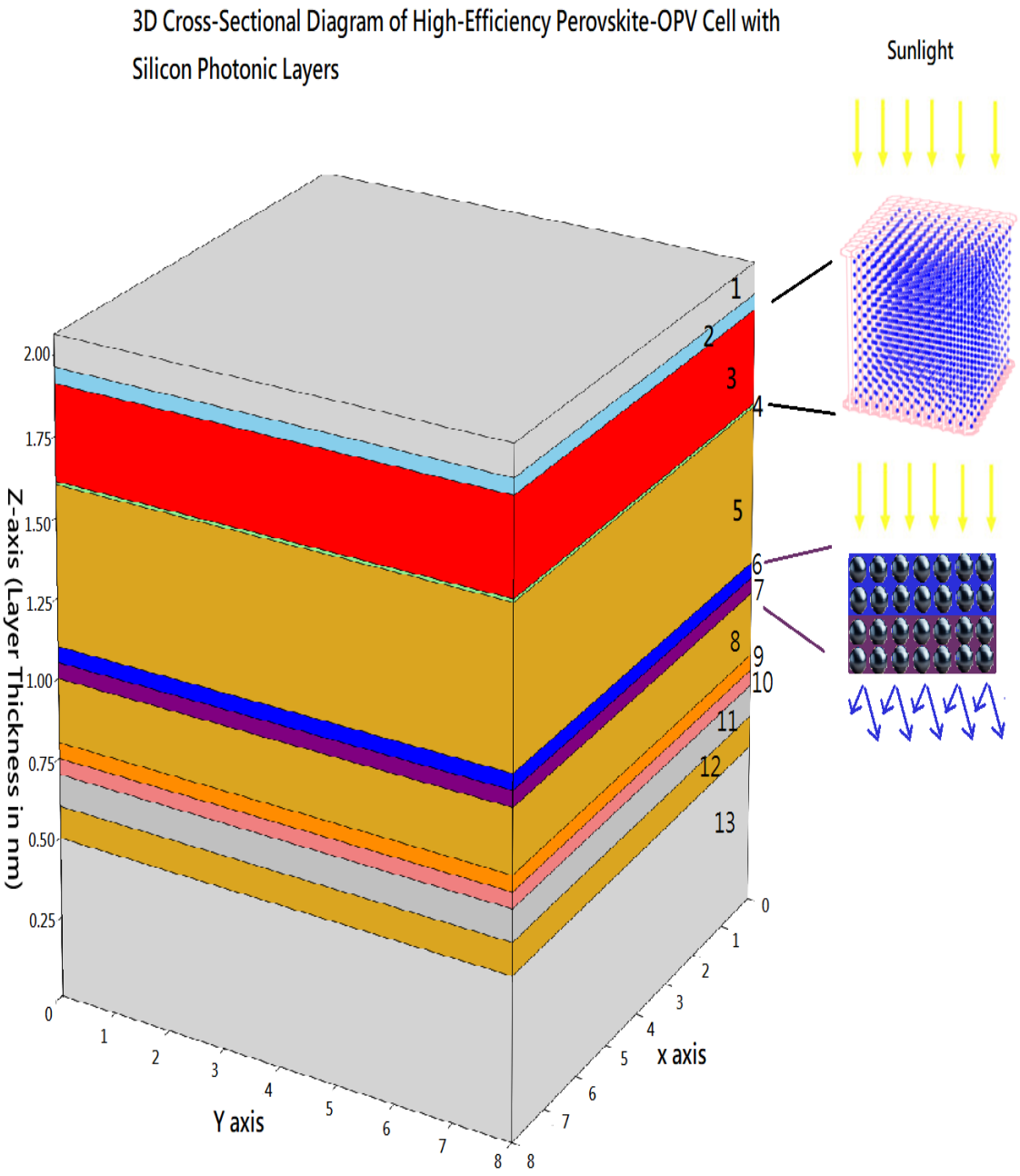
3D Cross-Sectional Diagram of High-Efficiency Perovskite-OPV Cell with Silicon Photonic Layers
Sunlight
Z-axis (Layer Thickness in nm)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
Y axis
x axis
1
2
3
4
5
6
7
8
9
10
11
12
13

Figure 2

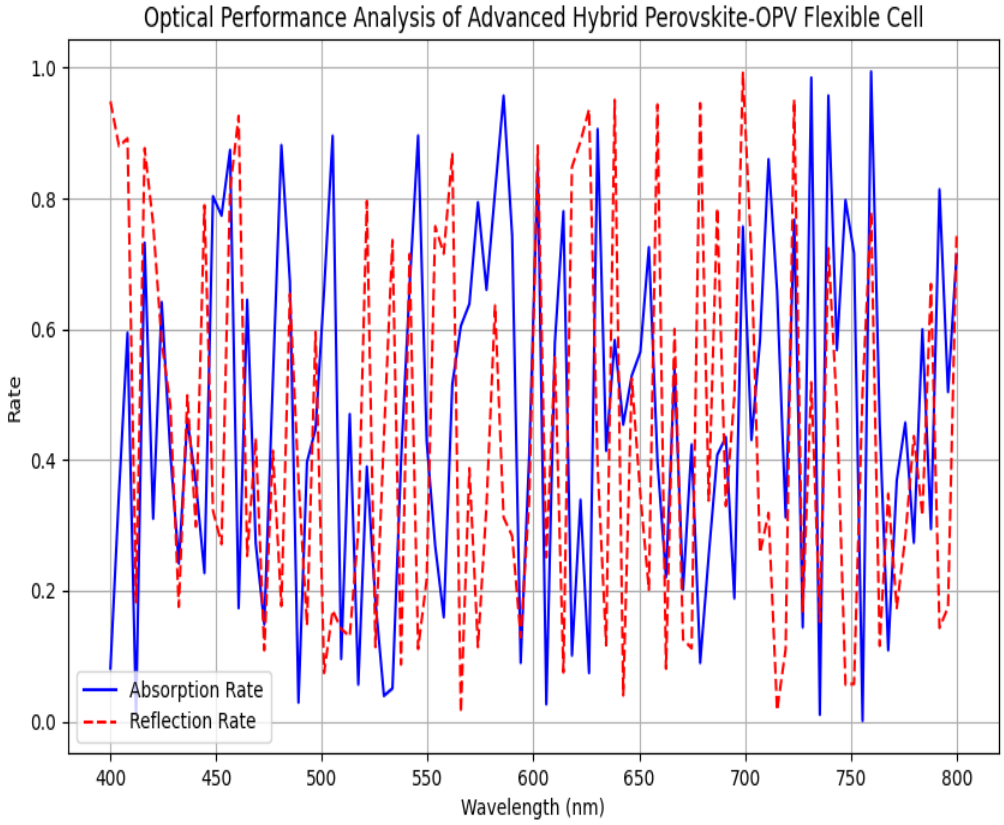

Figure 3

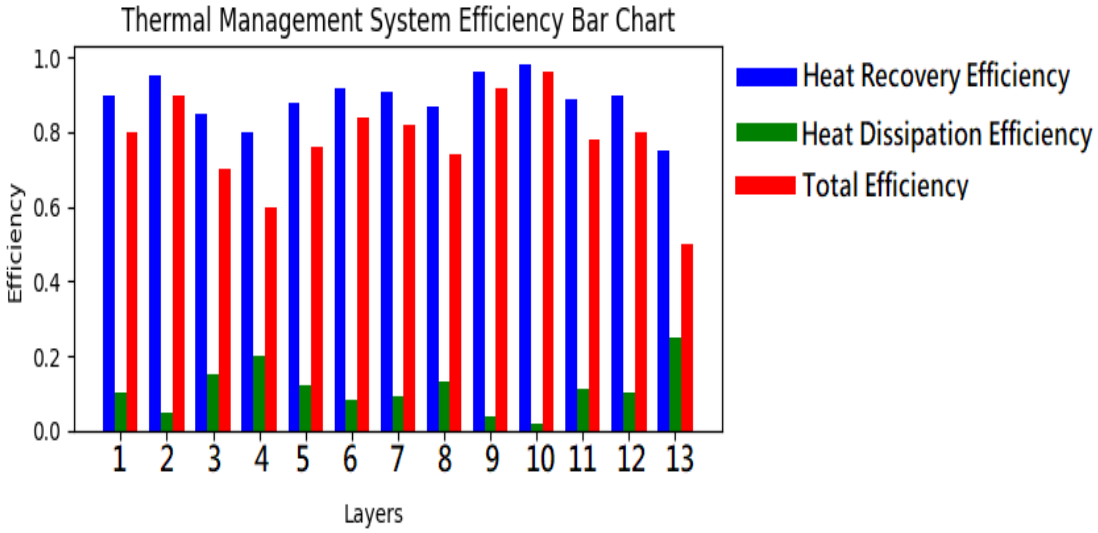

Figure 4

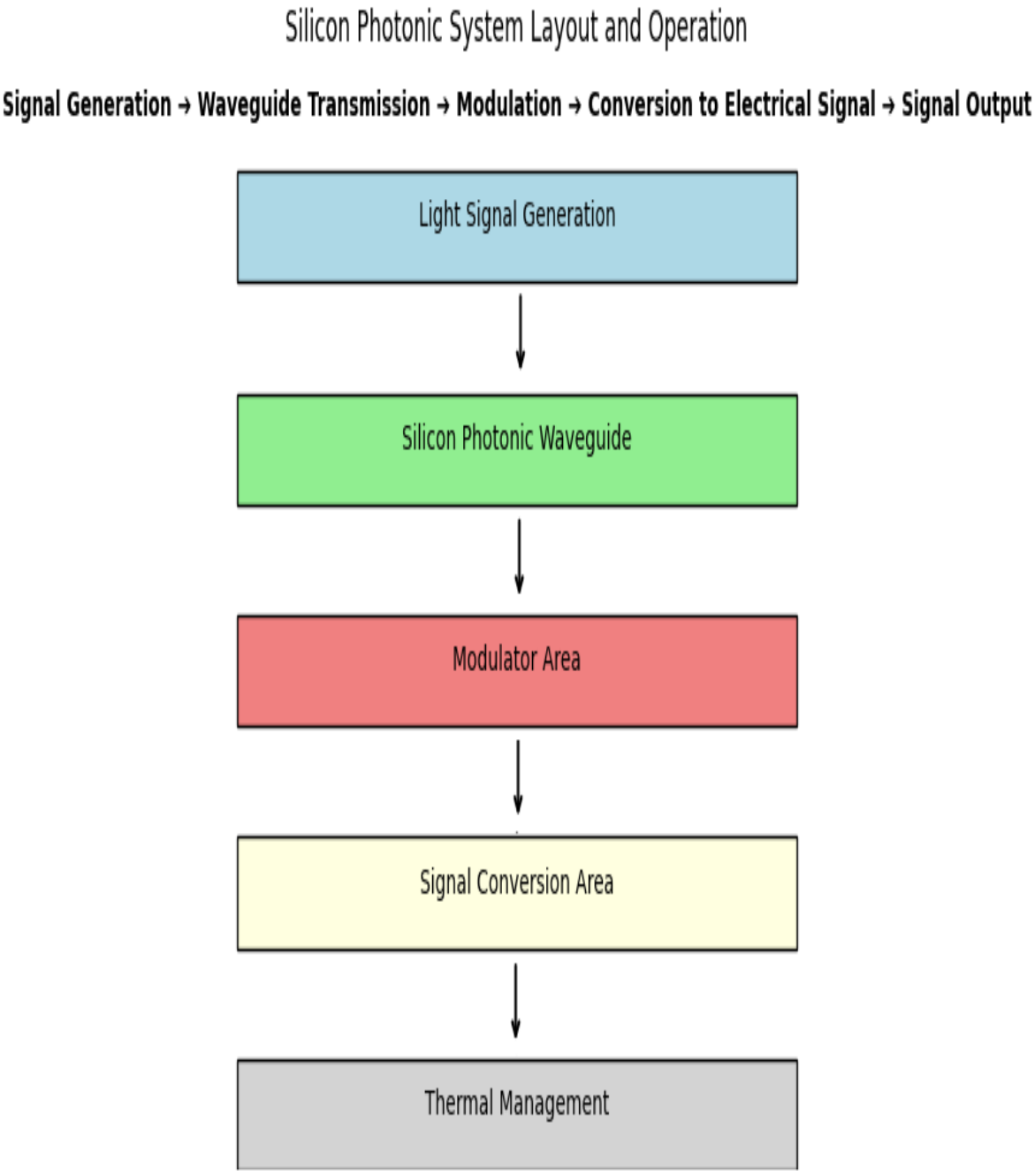
Silicon Photonic System Layout and Operation
Signal Generation → Waveguide Transmission → Modulation → Conversion to Electrical Signal → Signal Output
Light Signal Generation
Silicon Photonic Waveguide
Modulator Area
Signal Conversion Area
Thermal Management

Figure 5

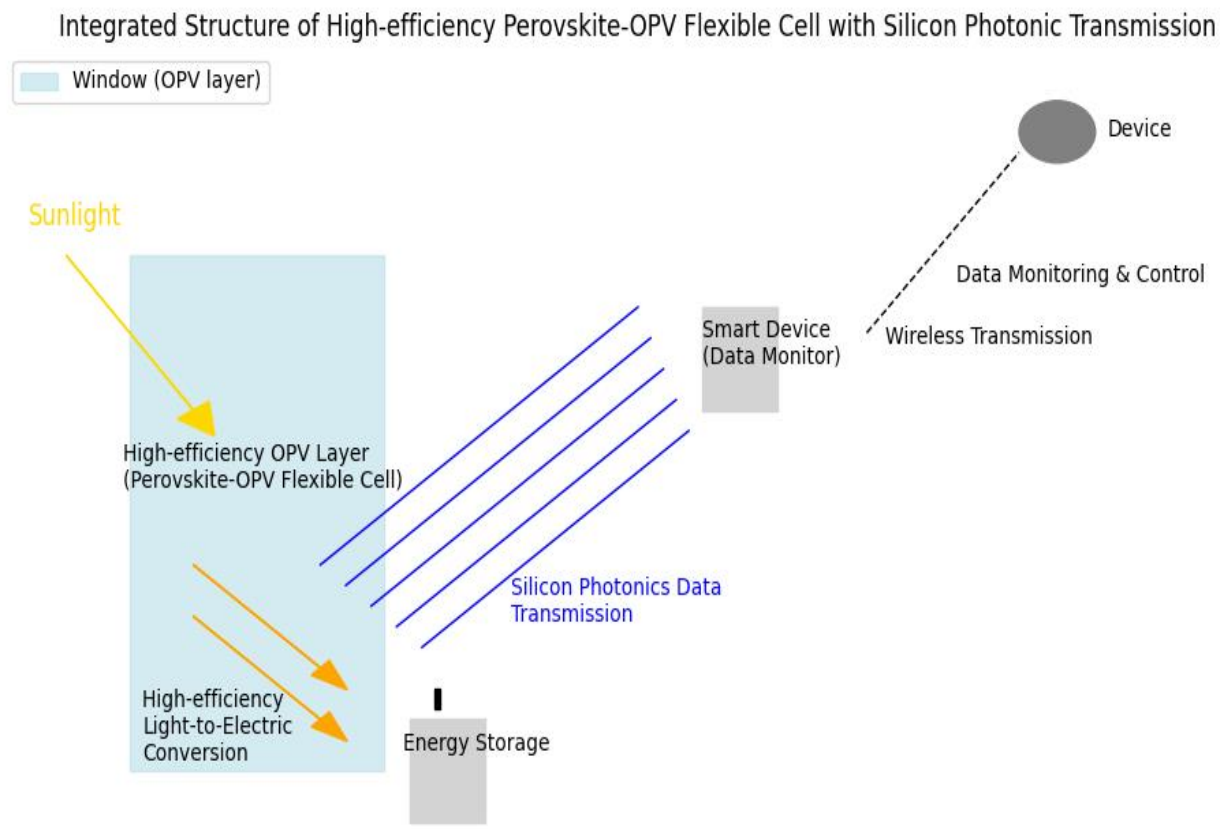

Figure 6-1

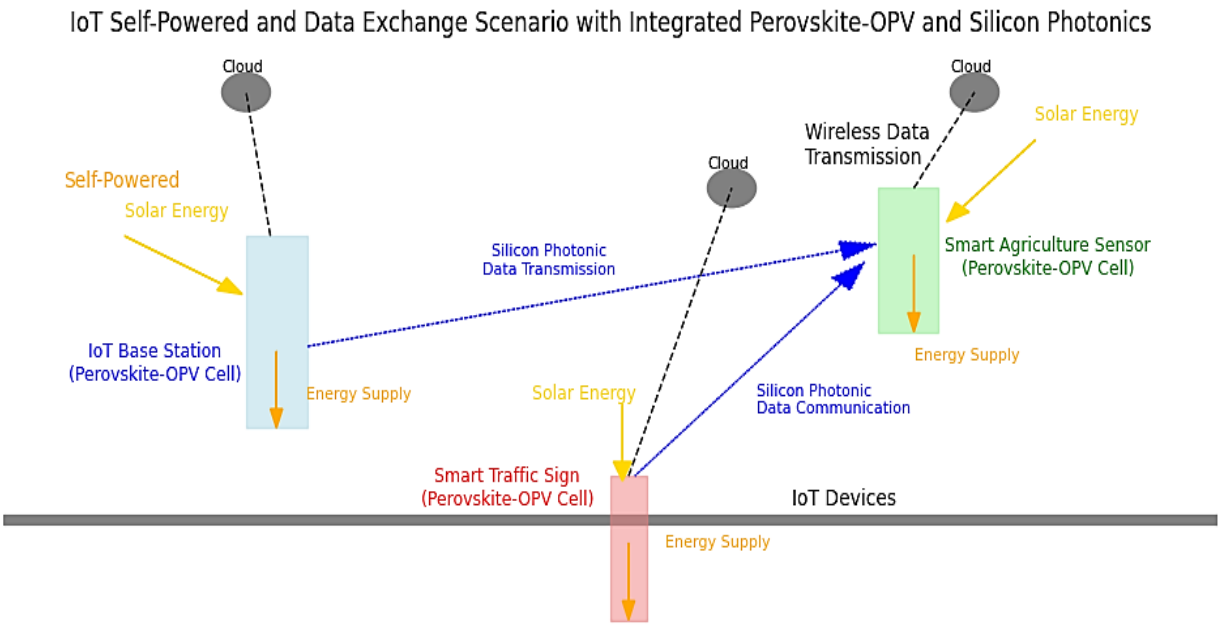

Figure 6-2

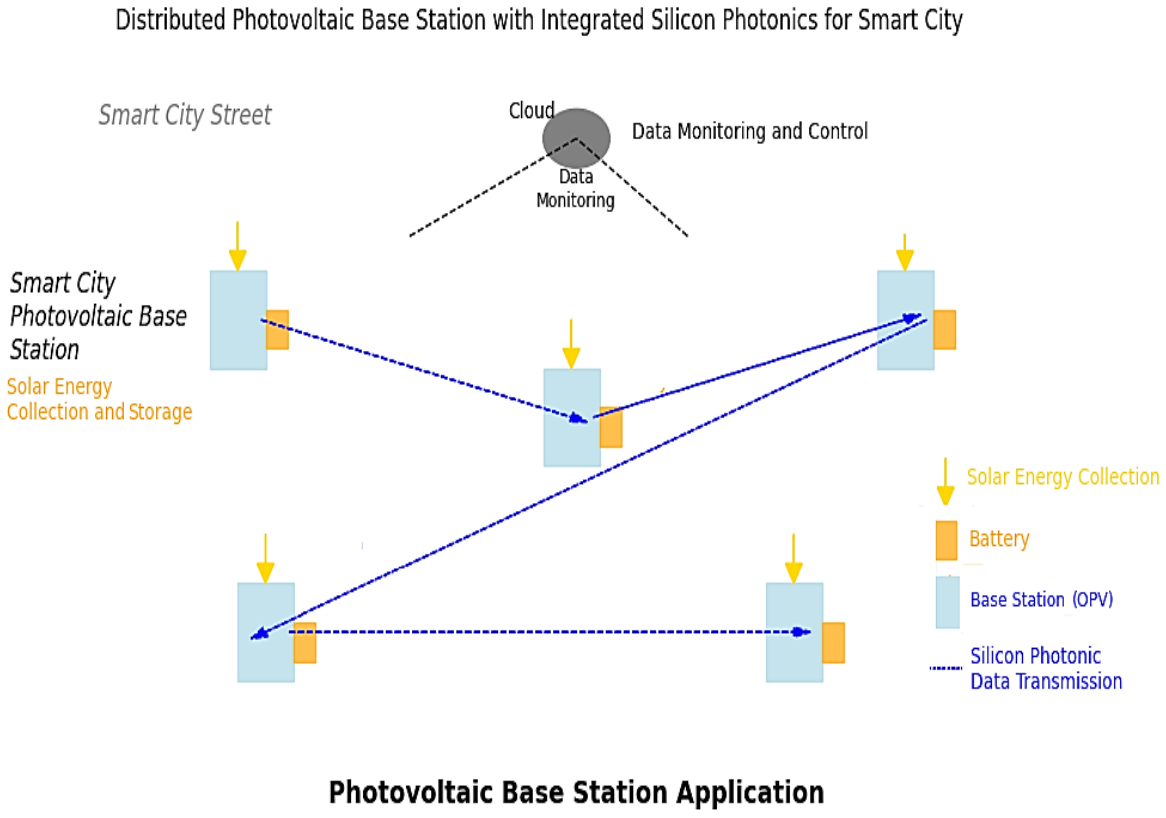
Distributed Photovoltaic Base Station with Integrated Silicon Photonics for Smart City
Smart City Street
Cloud
Data Monitoring and Control
Data Monitoring
Smart City Photovoltaic Base Station
Solar Energy Collection and Storage
Solar Energy Collection
Battery
Base Station (OPV)
Silicon Photonic Data Transmission
Photovoltaic Base Station Application

Figure 6-3