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两级聚光光伏系统中砷化镓电池特性的实验研究

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摘　要: 针对一般聚光系统中光斑不均匀而导致电池性能下降的问题, 设计并搭建了具有二级聚光器的碟式聚光光伏发电系统, 介绍了系统的结构及工作原理, 进行了户外实验。在相同聚光比条件下(150X) , 与单级聚光系统相比, 三结砷化镓光伏电池的平均峰值功率为 1.515 W/cm^2, 平均效率为 29.29%, 平均峰值功率和平均效率分别提高了 23.32% 和 9.12%。

关　键　词: 聚光光伏系统; 二级聚光; 三结砷化镓光伏电池; 峰值功率; 平均效率

中图分类号: TM914　　文献标识码: A

引　言

目前, 应用在太阳能聚光光伏系统中的聚光器主要有菲涅尔式和反射式两种形式, 由于加工工艺和材料等诸多因素的影响, 无论是菲涅尔透镜还是抛物面反射镜, 聚光时的光斑都不均匀, 导致电池表面温度不均匀及电池阵列电阻不均匀, 从而降低了电池的输出性能, 而且聚焦倍数越大这种影响越明显[1~2]。因此需要在聚光光伏系统中增加第二级聚光器以提高系统的性能。已有研究表明, 二级聚光系统的效率要高于单级聚光系统, 尤其是在直射辐照强度较小时, 二级聚光系统的效率要明显大于单级聚光系统[3~6]。

利用搭建的碟式太阳能二级聚光光伏系统研究高倍聚光条件下三结砷化镓电池的输出特性和影响因素, 为进一步开发该类型的光伏发电系统提供参考。

1　实验系统与测量设备

1.1　实验系统

上海理工大学动力二馆楼顶搭建的碟式太阳能聚光光伏系统如图 1 所示, 包括太阳追踪器、太阳能电池组件、传动机构、聚光器和支架, 其中旋转抛物面聚光器、跟踪控制系统和太阳电池组件是碟式太阳能聚光光伏系统中最重要的组成部分。光电转换装置包括聚光太阳电池组件、散热器等。采用的光伏电池为三结聚光 GaInP/GaInAs/Ge 叠层光伏电池, 如图 2 所示, 这种光伏电池具有光吸收系数大、抗辐射性能好、温度系数小、光电转换效率较高等优点。电池芯片面积为 10 mm × 10 mm, 电池底板为高导热材料, 在电池的下方有正负电极, 用于连接相关的电参数测量设备, 在正负电极之间是旁路二极管, 作用是防止太阳能电池在强光下由于遮挡导致光照的不均匀而造成的热斑效应, 避免光伏电池因严重发热而受损[7]。

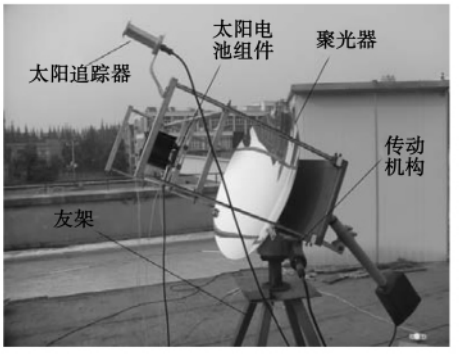

图 1　太阳能碟式聚光光伏系统
Fig. 1 Dish-type concentration photovoltaic system

图 2　三结聚光 GaInP/GaInAs/Ge 叠层光伏电池
Fig. 2 Three-junction GaInP/GaInAs/Ge layer-on-layer photovoltaic cell

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1.2　测量设备

碟式太阳能聚光光伏系统性能测试系统如图 3 所示。光伏系统温度包括光伏电池温度、翅片式热管散热器温度，利用 T 型热电偶测量，由 Agilent 34970 数据采集仪自动记录; 光伏系统电参数包括开路电压 V_{oc}、短路电流 I_{sc}、峰值功率 P_{mp}和转换效率 η，由 I－V 记录仪自动记录; 气象参数包括当地风速、温度、相对湿度、太阳总辐射强度 E_t、太阳直射辐射强度 E_d，由一台气象参数记录仪自动记录。上述所有数据均在电脑上由程序自行进行记录。

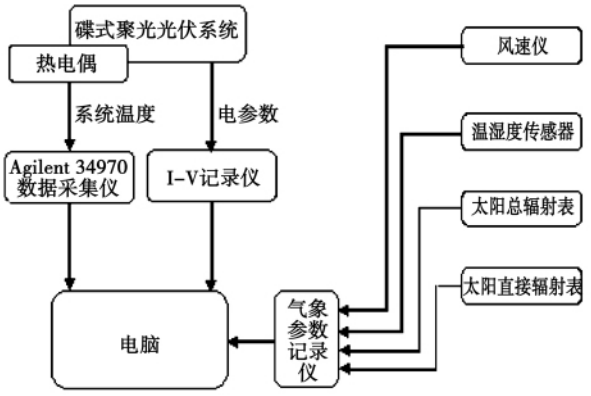

图 3　碟式聚光光伏系统性能测试系统

Fig. 3 Performance test system for dish type concentration photovoltaic systems

2　二级聚光器结构

2.1　聚光比

聚光比越大，所获得的太阳能光照强度越高，发电功率相等的情况下，节省电池板越多。三结聚光 GaInP/GaInAs/Ge 叠层光伏电池具有很好的高温特性，其聚光倍数可达 1000 倍以上[8]。

为了便于计算聚光比，作出假设:

(1) 聚光后形成的光斑均匀;

(2) 光斑的位置可按照旋转抛物面的几何公式进行计算。

结合上述假设，定义聚光比为[9]:

$$C = I_{scx}/I_{sc} \tag{1}$$

式中: I_{scx}—经聚光后光伏电池的短路电流; I_{sc}—未经聚光时，即 1 倍太阳光下电池的短路电流。

2.2　结构设计

二级聚光器结构如图 4 所示，采用精密注塑成型，采用真空直流溅射镀膜技术在其内壁镀上一层反射膜，反射率可达到 90%。二级聚光器为口部直径大、底部直径小的圆筒状形构件，三结砷化镓光伏电池板安装在二级聚光器的小直径底部端口处，太阳光经过二级聚光器的旋转曲面反射后可照射到底部的三结砷化镓光伏电池板上，三结砷化镓光伏电池板通过导热胶直接粘贴在散热板上，提高电池板的散热效果。太阳能电池组件受光面朝下，避免了污染物落到组件表面而产生的“热斑效应”，同时，可防止风沙、冰雹、雨水等对圆筒曲面内壁反射膜和三结砷化镓光伏电池板的破坏，延长了第二级聚光器的寿命并提高电池的使用寿命。

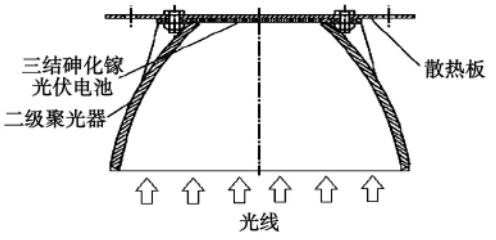

图 4　二级聚光器结构

Fig. 4 Structure of a two-stage concentrator

3　实验结果与讨论

图 5 ~ 图 8 为 2010 年 12 月 22 日碟式太阳能二级聚光光伏系统的实验结果，并在相同几何聚光比条件下与单级聚光系统的实验结果进行了比较。

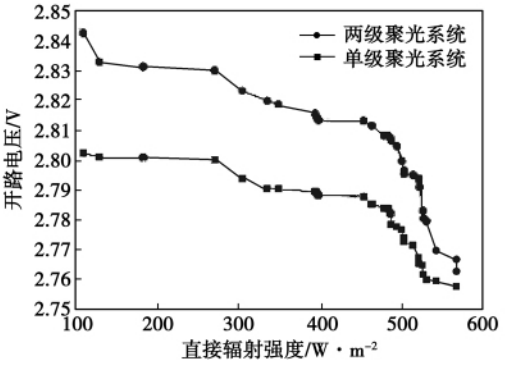

图 5　直射辐照强度对电池开路电压的影响

Fig. 5 Influence of the direct sun light radiation intensity on the open circuit voltage of a cell

三结聚光 GaInP/GaInAs/Ge 叠层光伏电池的开路电压随太阳直接辐射强度的变化如图 5 所示。随着直射辐照强度的增大，电池的开路电压逐步降低，

在相同直射辐照强度下，二级聚光系统光伏电池的开路电压要大于单级聚光系统时的开路电压：当直射辐射强度为 107 W/m^{2}时，有第二级聚光器时电池的开路电压为 2.842 9 V，而单级聚光时电池的开路电压为 2.802 26 V，两者相差 0.04 V；当直射辐照强度增大到 568 W/m^{2}时，有第二级聚光器时电池的开路电压为 2.762 35 V，而单级聚光时电池的开路电压为 2.757 2V，两者相差 0.005 15 V。这主要是因为，随着直射辐照强度的增大，光子通量密度变大，俄歇复合过程加强，成为主要的复合过程，且电池的温度随着直射辐照强度的增大而有所上升，从而导致开路电压的逐渐变小。

与电池开路电压的变化相反，三结砷化镓光伏电池的短路电流随着直射辐照强度的增加而变大，在相同直射辐照强度下，二级聚光时砷化镓电池的短路电流与单级聚光时的短路电流基本相同，如图 6 所示。当直射辐照强度为 107 W/m^{2}时，有第二级聚光器时电池的短路电流为 0.156 A，而无均光器时电池的短路电流为 0.122 A，两者相差 0.034 A；当直射辐照强度增大到 568 W/m^{2}时，有第二级聚光器时电池的短路电流为 1.487 A，而单级聚光时电池的短路电流为 1.492 A，两者相差 0.005 A。这主要是因为，光伏电池的短路电流会随着光子通量密度的增大而提高，因而电池的短路电流会随着直射辐照强度的增加而变大，在聚光比相同的情况下，即光子通量密度也相同，因此两者的短路电流也基本相同。

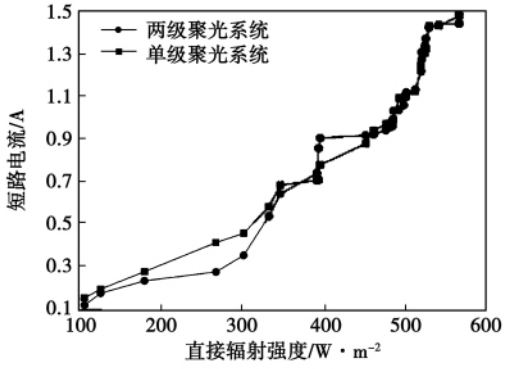

图 6 直射辐照强度对电池短路电流的影响

Fig. 6 Influence of the direct sun light radiation intensity on the short-circuit current of a cell

与电池开路电压的变化相同，随着直射辐照强度的增加，三结砷化镓光伏电池的峰值功率逐步变大，在相同直射辐照强度下，二级聚光时砷化镓电池的峰值功率要大于单级聚光时的峰值功率，如图 7 所示。当直射辐照强度为 107 W/m^{2}时，有第二级聚光器时电池的峰值功率为 0.429 W，而单级聚光时电池的峰值功率为 0.285 W，两者相差 0.144 W；当直射辐照强度增大到 568 W/m^{2}时，有第二级聚光器时电池的峰值功率为 1.872 W，而单级聚光时电池的峰值功率为 1.532 W，两者相差 0.34 W。这主要是因为，电池短路电流的增幅要大于开路电压的降幅，从而使得电池峰值功率的提升。

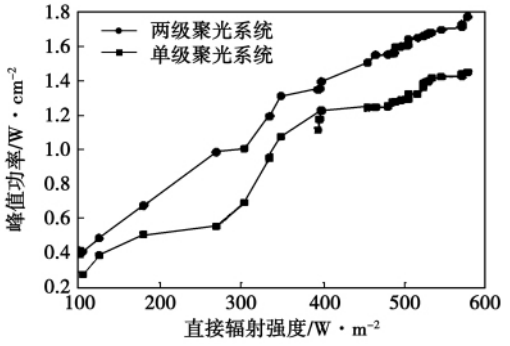

图 7 直射辐射强度对电池峰值功率的影响

Fig. 7 Influence of the direct sun light radiation intensity on the peak power of a cell

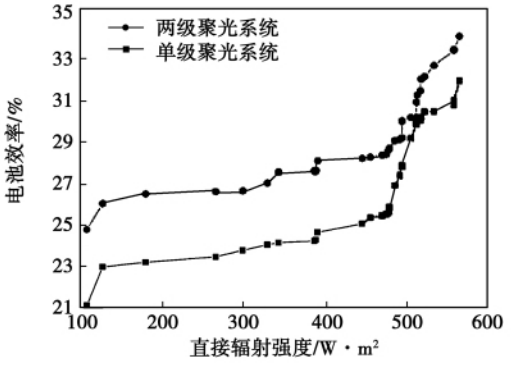

图 8 直射辐射强度对电池转换效率的影响

Fig. 8 Influence of the direct sun light radiation intensity on the conversion efficiency of a cell

直射辐照强度对三结砷化镓聚光型光伏电池的转换效率的影响如图 8 所示。与电池的开路电压变化相同，随着直射辐照强度的增大，砷化镓电池的转换效率逐步变大，在相同直射辐照强度下，有第二级聚光器砷化镓电池的转换效率更高：当直射辐照强度为 107 W/m^{2}时，有第二级聚光器时电池的转换效率为 24.761%，而单级聚光时电池的转换效率为 21.116%，两者相差 3.645%；当直射辐照强度增大到 568 W/m^{2}时，有第二级聚光器时电池的转换效率

为 34.086%，而单级聚光时电池的转换效率为 31.959%，两者相差 2.127%。

4 结　论

设计并搭建了一种碟式高倍二级聚光光伏发电系统，分析了直射辐射强度以及第二级聚光器对三结聚光 GaInP/GaInAs/Ge 叠层光伏电池在聚光比为 150X 下输出特性的影响，研究表明:

(1) 与单级聚光光伏系统相比，在使用第二级聚光器时，光伏电池的开路电压和峰值功率均有所增加，但增加幅度随着直射辐照强度的升高而减小。当直射辐照强度为 107 W/m^2，开路电压为 2.842 9 V，峰值功率为 0.429 W，较单级聚光光伏系统分别增加了 0.04V 和 0.144 W; 当直射辐照强度为 568 W/m^2，开路电压为 2.762 35 V，峰值功率为 1.872 W，较单级聚光光伏系统分别增加了 0.005 15V 和 0.34 W。而短路电流基本与单级聚光光伏系统相同。

(2) 二级聚光光伏发电系统的平均单位面积发电功率和效率分别提高了 23.32% 和 9.12%，因此在设计高倍聚光光伏系统的时候，应尽量引入二级聚光器。

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(丛　敏　编辑)

新技术、新设计

降低柴油发动机燃料供给系统耗量和压力波动

目前，在柴油发动机中燃料供给是借助容积泵(活塞式)，这会引起压力和耗量的较大波动。

第一，导致供油系统漏压概率升高; 第二，导致向燃烧室不均衡供油和内燃机不稳定工作。

研制和鉴定一系列液体介质波动过程稳定剂，高性能在船用管道，石油管道，输油管道，各种机器的液压管路得到证明。在内燃机供油系统的应用可降低波动，并可提高发动机工作的可靠性和稳定性。

(如需要以上技术，可与编辑部联系)

定壁温下甲烷自热重整产氢暂态特性数值模拟 = Nuerical Simulation of the Transient Characteristics of the Methane Self-heat Reforming-based Hydrogen Production at a Given Wall Temperature [刊,汉] ZHANG Li, ZHANG Miao, YAN Yun-fei (Power College, Chongqing University, Chongqing, China, Post Code: 400030), ZHANG Miao (Mechanical Industry No. 3 Designing Institute, Chongqing, China, Post Code: 400039) //Journal of Engineering for Thermal Energy & Power. -2012, 27(1). -112 ~ 116

By adopting the detailed reaction mechanism governing the methane self-heat reforming and through using a numerical simulation method, studied was the self-heat reforming reaction of $CH_4/O_2/H_2O$ Ni-based catalytic agent in straight microchannels. The influence of the constituents of the mixture and the mass flow rate on the self-heat reforming hydrogen-production transient characteristics was mainly analyzed. The research results show that at a relatively high temperature, the time required for attaining a maximal H_2 production capacity at the outlet of the miniature reactor is substantially influenced by the mass flow rate of the gas mixture but influenced relatively little by the constituents of the mixture. The time required for attaining a stable hydrogen production capacity is shortened with an increase of the H_2O/CH_4 mol ratio and extended with an increase of the O_2/CH_4 mol ratio. When the $CH_4/O_2/H_2O$ mol ratio is 1∶0.5∶3.5, the hydrogen volumetric fraction can be stabilized at 54% in a shortest time periof of 90 ms. **Key words:** microchannel, methane, self-heat reforming, transient characteristics

风力机叶片动力特性实验台设计 = Design of a Test Rig for Testing the Power Characteristics of a Wind Turbine [刊,汉] LI Hai-bo, LU Xu-xiang, LI Lu-ping, DENG Xiao-hu (Hunan Provincial Key Laboratory on "Renewable Energy Source Electric Power Technology", Changsha University of Science and Technology, Changsha, China, Post Code: 410004) // Journal of Engineering for Thermal Energy & Power. - 2012, 27(1). -117 ~ 121

Designed and developed was a wind turbine blade dynamic characteristics testrig, on which a wind turbine blade static load test, mode test, blade testing, blade non-destructive inspection, propeller and blade icing attached substance load simulation test, propeller and blade fatigue load test and destructive testsetc. can be performed. On this basis, the composition of the equipment items, structural features and the main functions of the test rig were described. On the test rig, a static load and mode test of a wind turbine blade were conducted and a 6-order mode parameter of the wind turbine blade was obtained. The MAC and MOV two mode criteria were used to verify the test results. **Key words:** wind turbine blade, dynamic characteristics, static load, mode test

两级聚光光伏系统中砷化镓电池特性的实验研究 = Experimental Study of the Characteristics of a Gallium Arsenide Cell in a Two-stage Concentrated Photovoltaic System [刊,汉] WANG Zi-long, ZHANG Hua, LI Ye

(College of Energy Source and Power Engineering, Shanghai University of Science and Technology, Shanghai, China, Post Code: 200093) //Journal of Engineering for Thermal Energy & Power. -2012, 27(1). -122 ~ 125

In the light of the problem that non-uniform light stains in a common photovoltaic concentration system lead to a degradation of the performance of a cell, designed and set up was a disk type photovoltaic concentration power generation system with a two-stage concentrator with the structure and working principle of the system being described and an outdoor test being conducted. At a same concentration ratio (150 X), the average peak power of a three-junction GaInP/GalnAs/Ge photovoltaic cell can be as high as 1.515 w/cm^2 and the average efficiency can attain 29.29%. Compared with a single-stage concentration system, the peak power and average efficiency increase by 23.32% and 9.12% respectively. **Key words:** photovoltaic system, two-stage concentration, three-junction GaInP/GalnAs/Ge photovoltaic cell, peak power, average efficiency

采用热重与红外光谱联用研究玉米秸秆热解 = Study of the Pyrolysis of Corn Stalk by Combining the Thermogravimetric Method with the Infrared Spectrum One [刊, 汉] XU Yan(Department of Energy Science and Engineering, Harbin Electric Power Vocational Technical College, Harbin, China, Post Code: 150030), ZHU Qunyi(College of Energy Science and Engineering, Harbin Institute of Technology, Harbin, China, Post Code: 150001), SONG Shao-guo(Heilongjiang Provincial Thermal Power No. 3 Engineering Project Corporation, Harbin, China, Code: 150016) // Journal of Engineering for Thermal Energy & Power. -2012, 27(1). -126 ~ 129

By using the thermogravimetric and Fourier Transform Infrared Spectroscopy combined technology (TG-FTIR), at a temperature rise speed of 20 ℃/min, experimentally studied were the pyrolytic products of various parts of the corn straw stalk (including straw stalk husk, straw stalk flesh, leaves and bracts) and their precipitation processes. The test results show that the pyrolytic products of various parts of the corn straw stalk are mainly CO_2, CO, CH_4 and H_2O etc. and in the meantime, involve substances such as propionic acid and its kind in a small amount. The precipitation of the pyrolytic gases from straw stalk husk and flesh assumes a single-peak shape and those from the leaves and bracts take on a dual-peak shape. The pyrolytic temperature corresponding to the maximal weight loss rate resulting from the pyrolysis of various parts of the corn straw stalk is around 360-371℃, having a smallest difference. For a same part of the corn straw stalk, the pyrolytic temperatures corresponding to the maximal weight loss rate resulting from the main pyrolytic products are basically identical. **Key words:** thermogravimetric analysis, Fourier Transform Infrared Spectroscopy (FTIR), corn straw stalk, pyrolysis