

非金属材料放气对砷化镓电池的影响分析

院小雪, 于钱, 臧卫国, 杨东升, 周晶晶, 姜海富

(北京卫星环境工程研究所, 北京 100094)

摘要: 目的 提高砷化镓电池的应用效率。方法 以航天器常用灰皮电缆作为放气源, 通过电池性能与透过率关系试验和污染物沉积量与透过率关系试验研究, 分析材料放气对砷化镓电池的性能影响。结果 随着非金属材料放气沉积量的增多, 砷化镓电池的短路电流不断减小。当污染沉积量达到 $4 \times 10^{-5} \text{ g/cm}^2$ 时, 砷化镓电池的短路电流变化量为 23 mA, 变化率为 10.9%; 当污染沉积量达到 $1.26 \times 10^{-4} \text{ g/cm}^2$ 时, 砷化镓电池的短路电流变化量为 42 mA, 变化率为 20.0%。结论 非金属材料放气是造成太阳电池性能下降的因素之一。

关键词: 非金属材料; 放气; 污染; 砷化镓电池; 透过率; 短路电流

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Effects of Outgassing of Non-metal Materials on GaAs Solar Cell

YUAN Xiao-xue, YU Qian, ZANG Wei-guo, YANG Dong-sheng, ZHOU Jing-jing, JIANG Hai-fu

(Beijing Institute of Spacecraft Environment Engineering, Beijing 100094, China)

ABSTRACT: Objective To improve the application efficiency of GaAs solar cell. **Methods** Grey-cables that were commonly used for spacecrafts were taken as the outgassing source, the effects of outgassing of non-metal materials on GaAs solar cell were analyzed through the relationship test between the power of solar cell and transmittance and the relationship test between the depositing mass of contaminants and transmittance. **Results** The short circuit current of GaAs solar cells decreased with the increase of deposition of outgassing of non-metal materials. The short circuit current of GaAs solar cells decreased by 23 mA and the variety ratio was 10.9%, when the depositing contaminants arrived at $4 \times 10^{-5} \text{ g/cm}^2$. The short circuit current of GaAs solar cells decreased by 42 mA and the variety ratio was 20.0%, when the depositing contaminants arrived at $6 \times 10^{-4} \text{ g/cm}^2$. **Conclusion** Outgassing of non-metal materials was one of the factors causing degenerated performance of solar cells.

KEY WORDS: non-metal materials; outgassing; contamination; GaAs solar cell; transmittance; short circuit current

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作者简介: 院小雪(1980—), 女, 河南南阳人, 硕士研究生, 高级工程师, 主要研究方向为航天器污染检测与控制。

Biography: YUAN Xiao-xue(1980—), Female, from Nanyang, Henan, Master's degree, Senior engineering, Research focus: contamination detecting and control for spacecraft.

太阳电池阵作为航天器电源系统的关键组件之一,其性能衰变将直接影响电源系统的工作状态,从而影响整个航天器的工作状态^[1-3]。目前,航天器普遍采用三结砷化镓太阳电池。太阳电池在轨运行期间,会受到紫外辐照、原子氧、碎片、等离子体、温度和污染等多种空间环境及诱导环境的影响^[4]。

太空中,对砷化镓电池产生污染的污染源主要有:航天器用非金属材料放气^[5-6];姿控发动机的喷射^[7];空间环境的影响^[8-10]。其中,非金属材料放气是污染源的重要组成部分。航天器真空热试验中污染监测试验的结果表明,非金属材料放气释放的有机分子主要为邻苯二甲酸酯类和硅氧烷类^[11-13]。

文中以非金属材料灰皮电缆放气产物邻苯二甲酸酯类为例,分析其对砷化镓电池的性能影响,从而为太阳电池的污染防治提供依据和支持。

1 试验

非金属材料放气对砷化镓电池性能影响试验包括两部分:砷化镓电池性能与透过率关系试验和污染物沉积量与透过率关系试验。通过这两组试验,得到污染物沉积量与太阳电池功率损失之间的关系。

1.1 材料及设备

试验用品包括砷化镓电池、石英光学试片和非金属材料等。砷化镓电池尺寸为3 cm × 4 cm,短路电流为210 mA,石英光学试片尺寸为80 mm × 80 mm × 1 mm。非金属材料为航天器常用灰皮电缆,其放气产物为邻苯二甲酸酯类,无色透明液体。

砷化镓电池的性能测试采用太阳模拟器和数字万用表,测试其短路电流,测量电路如图1所示。

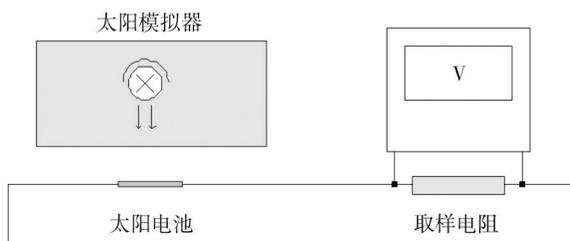


图1 太阳电池短路电流测试电路

Fig.1 The sketch map of the electrocircuit test for short circuit of solar cell

用U-3900H紫外可见分光光度计测试石英光学试片的光学透过率,其波长范围为190 ~ 900 nm,光谱带宽为0.2 ~ 4.0 nm。采用石英晶体微量天平测量非

金属材料的放气沉积量^[14],其谐振频率为20 MHz,污染量测试精度为 $1.1 \times 10^{-9} \text{ g/cm}^2$,污染量测试范围为 $0 \sim 1.1 \times 10^{-5} \text{ g/cm}^2$ 。

1.2 试验方案

1) 砷化镓电池性能与透过率关系试验。试验如图2所示,分别将1,2,5块光学试片放置在太阳电池片上,进行模拟光照下的短路电流测试,从而得到砷化镓电池功率损失与透过率影响之间的关系。测试过程中,将太阳电池片正对太阳模拟器光源,使光线垂直入射,按照砷化镓电池短路电流测试电路示意图进行测试。

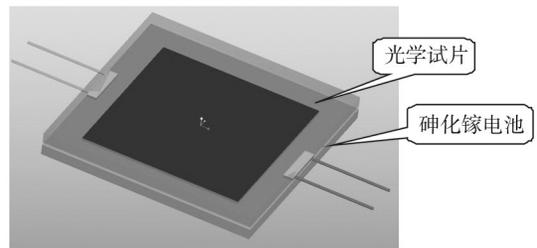


图2 透过率影响试验

Fig.2 The sketch map of transmittance effect test

2) 污染物沉积量与透过率关系试验。试验设备如图3所示,在样品室中放置灰皮电缆,将材料加热到125 °C进行烘烤,样品室开口朝向石英光学试片。分别进行不同时间的材料真空放气试验,在光学试片上形成 10^{-6} , 10^{-5} , 10^{-4} g/cm^2 量级的污染沉积量,从而得到污染物沉积量与透过率损失之间的关系。

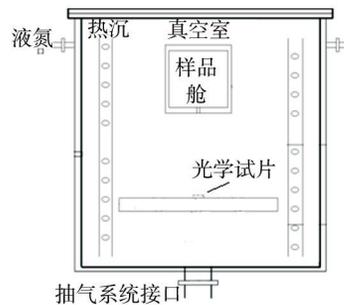


图3 材料放气试验

Fig.3 The sketch map of material outgassing test

2 结果和讨论

2.1 砷化镓电池功率损失与透过率影响试验

放置1,2,5块光学试片后的透过率分别为

91.90%, 85.00%, 58.01%。光学透过率损失结果与太阳电池短路电流变化的关系曲线如图4所示。

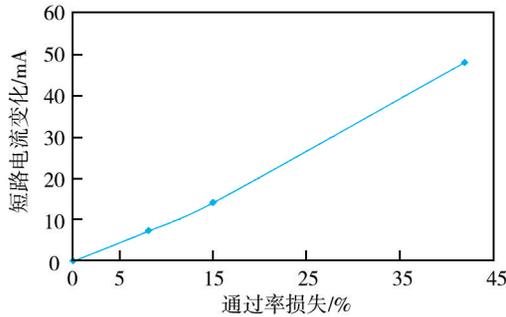


图4 光学透过率损失与太阳电池短路电流变化的关系曲线
Fig.4 The relationship between the transmittance loss and the short circuit of solar cell

2.2 污染物沉积量与透过率损失影响试验

真空放气沉积后的样品显微图像如图5所示,在光学试片表面形成颗粒状薄膜。针对不同量级的污染量,分别测试了在300~700 nm的透过率损失情况。测试结果见表1。

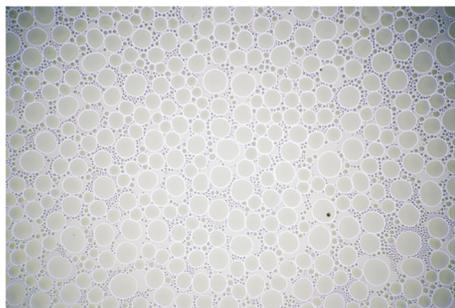


图5 真空放气沉积样品显微图像
Fig.5 The micrograph of the sample with depositing contaminants in vacuum environment

表1 光学试片透过率损失测试结果

Table 1 The test result of transmittance of optic glasses

样品编号	单位面积凝结质量($\times 10^{-6} \text{ g}\cdot\text{cm}^{-2}$)	基板透过率/%	凝结后透过率/%	透过率损失/%
1	1.05	93.6092	81.1204	12.4888
2	5.79	93.5969	80.1551	13.4481
3	15.7	93.7451	79.1981	14.543
4	28.9	93.7519	75.7825	17.9694
5	34.2	93.7624	72.0941	21.6683
6	106	93.4069	57.3175	36.0894
7	123	93.4798	55.9056	37.5742

光学透过率损失结果与污染沉积量关系曲线如

图6所示。

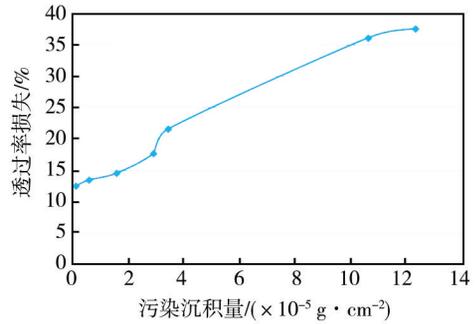


图6 光学透过率损失与污染量关系
Fig.6 The relationship between the transmittance loss and the mass of the contaminants

通过上述试验,得到非金属材料放气造成污染沉积量与砷化镓电池输出短路电流的关系,如图7所示。

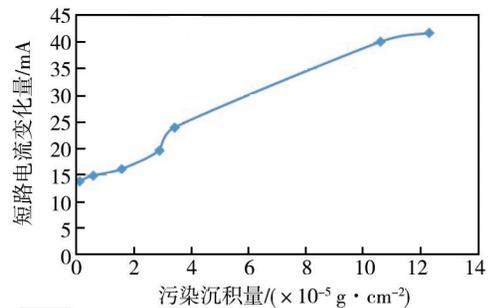


图7 污染沉积量与短路电流变化曲线
Fig.7 The relationship between the mass of the contaminants and the short circuit of solar cell

3 结论

通过对试验结果进行分析,可以得到如下结论。

1) 随着非金属材料放气沉积量的增多,砷化镓电池的短路电流不断减小。

2) 当污染沉积量达到 $4 \times 10^{-5} \text{ g}/\text{cm}^2$ 时,砷化镓电池的短路电流变化量为23 mA,变化率为10.9%;同时曲线的斜率减小,砷化镓电池的短路电流变化率减小。

3) 当污染沉积量达到 $1.26 \times 10^{-4} \text{ g}/\text{cm}^2$ 时,砷化镓电池的短路电流变化量为42 mA,变化率为20.0%;同时曲线平缓,砷化镓电池的电流值基本趋于平稳。

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