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Study on the Thermal Stress Distribution of Crystalline Silicon Solar Cells In BIPV

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Abstract

The working temperature of BIPV modules is high than ground-mounted PV. Based on the theory of material mechanics and thermal stress analysis, the stress distribution of metallization interconnects system for crystalline silicon solar module in BIPV was studied for the first time. The shear stress and normal stress distribution of soldered structure for crystalline silicon solar cell under the thermal field were discussed. And the results show the stress distribution is not simply linear relationship as some results found. But there is a stress concentration at the edge, which was considered as the true reason that caused V-notch at the edge of soldered solar cell. The conclusions we got in this paper provide a theoretical basis for reliability of c-Si BIPV modules.

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Keywords: BIPV; analytic model; crystalline silicon solar cell; shear force; stress distribution

1. Introduction

Crystalline silicon solar module is the critical component of photovoltaic (PV) generation system. Because of outdoor installation, the most defects and failures might occur on PV systems with respect to environment stresses. In fact, these stresses cause to emerge various electrical and mechanical faults on PV modules [1-2]. The effective control of power degradation is very important for the investment income and reliability of PV power station. The manufacturers usually guarantee that the lifetime of solar cell module is expected to be 25 years with 20% reduction in its power output over this period. Installed and operated in hot and humid climate, the typical operating temperature of PV modules will change between -30~+100℃. In the process of crystalline silicon solar module production, the crystalline silicon solar cells are interconnected into complete string. The cells of PV modules are electrically connected in series

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by interlacing tin-coated copper ribbon between the front of one cell and the back of the adjacent cell. Due to the large difference of coefficient of thermal expansion (CTE) between metal and silicon, thermal stress will appear and accumulate in metallization interconnect system when PV module is suffering from a temperature cycle. The cyclic thermal stress will cause micro-cracks and voids, which will increase the contact resistance of electrode and reduce PV modules' lifetime. Although many researches on module reliability have been done [3-5], there was no quantitative research for the thermal stress distribution inside the crystalline silicon solar module.

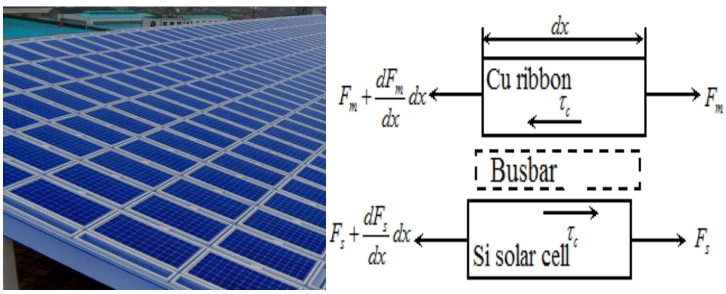
In this paper, a model of the thermal stress distribution of metallization interconnects system for crystalline silicon solar module is established for the first time. The shear stress and normal stress distribution of soldered structure for crystalline silicon solar cell under the thermal field were discussed. And the results show the stress distribution is not simply linear relationship as some results found [6-9]. But there is a stress concentration at the edge, which was considered as the true reason that caused V-notch at the edge of soldered solar cell.

2. Structure model of solar cells metallization interconnect system

2.1. Theoretical model

Considering the complicated structure, when the PV module is working outdoor and suffering from a temperature cycle, different thermal stress will be caused in different material which with different coefficient of thermal expansion(CTE). As the adhesion and restriction between each structure material, a kind of stress cycle will appear in the interface and gradually lead to various reliability problems like crack, low power or even failure [10].

The cells of PV modules are electrically connected in series by interlacing tin-coated copper ribbon. As we know, glass layer is the main binder phase at Ag paste/Si contact interface, and the peeling off of cell electrodes always occurred in Ag paste layer. The coefficients of thermal expansion of metal materials are quite different from Si substrate, while the glass frit is between metal and Si. As shown in Figure 1, a simplified structure model with only three-layer was established (Cu ribbon, Ag paste layer and Si substrate). Assume each layer satisfies the homogeneous, isotropic and linear conditions.



(a) BIPV (b) Mechanic analysis

Fig. 1. Mechanic analysis of the metallization interconnect system in BIPV

The thickness, width and Young's modulus of the layers are t_m , b_m and E_m for ribbon, t_s , b_s and E_s for Si substrate layer, and t_c , b_c , E_c for thin glass layer respectively, L is the bond length. Considering the