Electrical-Optical Characterization Of Multi-Junction Solar Cells Under 2000x Concentration

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In the framework of the FAE "Fotovoltaico ad Alta Efficienza" ("High Efficiency Photovoltaic") Research Project (PO FESR Sicilia 2007/2013 4.1.1.1), we have performed an electrical and optical characterization of commercial InGaP/InGaAs/Ge triple-junction solar cells mounted on a prototype HCPV module operating at 2000 suns, installed at Palermo (Italy). This system uses a reflective optics based on rectangular off-axis parabolic mirror with aperture 46x46 cm^2. The sunlight flux incident on the mirror is focused on the face of a BK7 glass frustum in optical contact with 1 cm^2 solar cell; in this manner, a geometrical concentration ratio 2116 is realized. The solar cell under test is mounted on a receiver by a heat sink with passive cooling so as to remove the heat produced by concentrated sunlight.

- Electrical characterizations. In order to estimate instantaneous power output and system efficiency we record the I-V curve, about 1000 data points with an acquisition time lower than 10 ms, from which we extract in real time the most important electrical parameters, such as the maximum power (P_{MP}), the short-circuit current (I_{sc}), the open-circuit voltage (V_{oc}) and the fill factor (FF). The rapid acquisition time reduces the conversion from electric to thermal power thus ensuring that the cell temperature, monitored via a PT100 thermal sensor, does not change during the measurement. Figure 1 shows a typical I-V characteristics measured in our HCPV prototype in a sunny day at 12:30 on October 19, 2013. Under an irradiation intensity of 700 W/m^2, measured with a pyrheliometer, we get a P_{MP} of 41.36 W.
- Optical characterizations. We focus our attention on electroluminescence (EL) and photoluminescence (PL) features. Figure 2 shows EL emitted from a InGaP/InGaAs/Ge triple-junction solar cell under a current injection of 500 mA in forward bias, the temperature could be controlled by a Peltier-based system. The spectra were acquired by an optical fiber spectrophotometer equipped with a CCD camera active in the range 300-1000 nm thus allowing to measure the emission around 680 nm from the top (InGaP) and the emission around 890 nm from the middle (InGaAs) subcells. On increasing the temperature in the range 25÷100 °C we observed a red-shift of the peaks that agrees with the temperature dependence of the Energy gap associated with InGaP and InGaAs, respectively. As indicated by Rau et al. [1] this investigation is complementary with the study of the I-V curves and helps to predict the response of a multi-junction solar cells under concentration 2000X with models based on the equivalent circuit [2].

References

[1] U. Rau, "Reciprocity relation between photovoltaic quantum efficiency and electroluminescent emission of solar cells," *Physical Review B* 76 (8), 2007.

[2] P. Rodrigo *et al.*, "Models for electrical characterization of high concentration photovoltaic cells and modules: A review", *Renewable and Sustainable Energy Reviews* 26, 2013, 752-760.

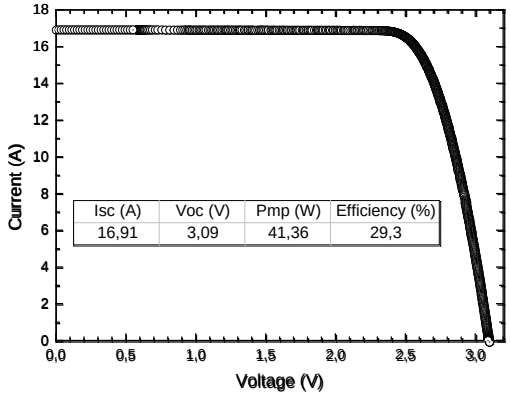

FIGURE 1. I-V curve obtained by a commercial InGaP/InGaAs/Ge solar cell under test with an indoor irradiance of about 700 W/m^2.

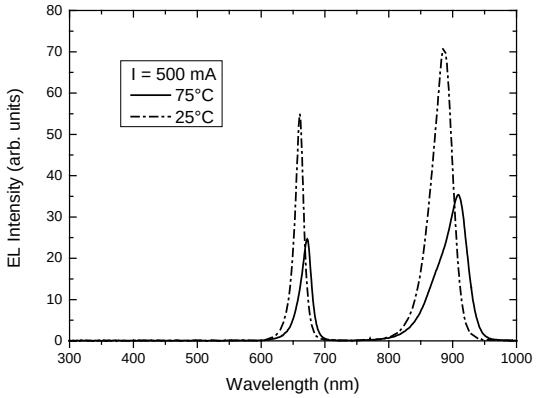

FIGURE 2. Spectrally resolved EL at two different temperatures from the top and middle subcells of a commercial InGaP/InGaAs/Ge solar cell under test.