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Topic

Fabrication, Characterization and other Related Studies for Performance Improvement of Crystalline Silicon Solar Cells

Abstract

This thesis investigates the role of series and shunt resistances, their accurate measurements, their temperature dependence and their effects on solar cell performance. Effect of inhomogeneity of R_{sh} (in large area solar cell) on the performance of solar cell was also studied. In this work, the conventional n^+-p-p^+ structure based silicon solar cells were fabricated with screen printed metallization and on some of them a low cost porous silicon layer was deposited in order to reduce the reflective losses.

A new method for the determination of the series (R_s) and shunt resistances (R_{sh}) in silicon solar cells was developed during the course of the work. The method is based on the single exponential model and utilizes the steady state illuminated I-V characteristics in 3rd and 4th quadrants and the V_{oc}-I_{sc} characteristics of the cell. It enables determination of values of R_{sh} and R_s with the intensity of illumination and junction voltage. The method shows that R_{sh} of a silicon solar cell is nearly independent of intensity of illumination but the series resistance decreases with both the intensity of illumination and the junction voltage. Results have been published in **Solar Energy Material and Solar Cells, 91 (2007) 137–142**.

The temperature dependence of open circuit voltage (V_{oc}) and curve factor (CF) of a silicon solar cell has been investigated in 295K-320K temperature range. The rate of decrease of V_{oc} with temperature (T) is controlled by the values of the band gap energy (E_g), shunt resistance (R_{sh}) and their rates of change with T. We have found that R_{sh} decreases linearly with T and its affect on dV_{oc}/dT is significant for cells having smaller R_{sh} values. Series resistance decreases linearly with voltage. CF depends not

only on the value of R_s and other parameters but also on the rate of change of R_s with voltage. Results have been published in **Solar Energy Material and Solar Cells, 92 (2008) 1611–1616**.

For study of inhomogeneity in ARC the front surface of two solar cells XA and was investigated using X-ray photoelectron spectroscopy (XPS), scanning electron microscope (SEM) and reflectivity measurement. XPS results have shown that carbon and oxygen were not only found on the silicon substrate surfaces but also on the final solar cell device i.e. in the Si_3N_4 anti-reflection coating. This indicates that in the processing steps where organic substances (screen printing) were involved, not all organics were removed during the thermal treatments. For the solar cell XB it was found that the concentration of carbon, oxygen were higher at surface and texturing was more irregular and therefore the cell exhibited less satisfactory photovoltaic performance. Results have been published in **Solar Energy Material and Solar Cells 93 (2009) 19–24**.

The localized inhomogeneity in shunt resistance of another large area solar cell and its effect on the performance, particularly, on spectral response of the solar cell was investigated. The study shows that simultaneous presence of the regions of low shunt resistance and large series resistance can drastically affect the measurement of the spectral response of the cell. The results have been published in **IEEE 4th World Conference Photovoltaic Energy Conversion, Conference 1 (2006) 1242 – 1244.**

In order to reduce reflection losses from silicon surface a low cost porous Si film was used as an antireflection (AR) coating. The PS films, formed on polished p type Si wafer with Ag as the back contact are superior in properties as compared to Al-back contact PS films under the same conditions of anodization in terms of higher porosity, better film-substrate adherence, higher PL intensity, lack of decay in PL intensity. The application of the PS ARC on n+ emitter of a solar cell leads to a ~20.8% relative improvement in photocurrent, a significant gain in open-circuit voltage of ~15mV and a relative increment in fill factor of about ~ 1.3%. This yields a ~26% increase in efficiency. It is confirmed by the I-V and SEM measurements that this PS ARC does not degrade the electrical contact of the unprotected front metallic grid pattern. The results have been published in **Solar Energy Material and Solar Cells 91 (2007) 1510–1514 and Advanced Materials Research Vol. 31 (2008) pp. 249-253.**