Abstract

In tandem solar cells two or more solar cells share the solar spectrum. The structure consists of two sub-cells on top of each other, with the top cell absorbing the blue photons and the bottom cells absorbing the red photons. Tandem cells on silicon are interesting because they provide a pathway for more efficient commercial solar cells. Two problems of current tandem cells on silicon are: low-loss tunnel junction and efficient absorbing semiconductor for the top subcell.

The first part of the thesis deals with the design of tunnel diodes. Tunnel diodes are used at the interface of the two sub-cells to enable passage or transport of carriers from one cell to another by the quantum mechanical phenomenon of tunneling. Low-loss tunnel junctions offer a low resistance and optically transparent connection between two sub cells. Here we report "all-oxide" heterojunction diodes which have the potential to behave like tunnel junction diodes. For this study we chose nitrogen doped $\mathrm{Cu_2O}$ as the p+-type material and ITO as the n+-type material, both deposited using magnetron sputtering. The primary materials challenge is deposition of degenerately doped oxide thin-films. Through careful optimization of deposition conditions highly-doped Cu2O and ITO films with a peak doping concentration of 2.6 x 10^{18} cm^{-3}, and 2.0 x 10^{19} cm^{-3} were obtained. Next, tunnel diodes with p+-$\mathrm{Cu_2O}$/n+-ITO structure in various configurations were fabricated. Negative differential resistance, the characteristics feature in the I-V characteristics of a tunnel diode, was not observed in any of the devices. This could occur due to several reasons: a) the I-V characteristics of the tunnel devices may be reflecting the series resistance due to the bulk resistance of the constituent layers, b) the thermal generation current due to the bulk and interface defects may be much higher than the tunneling current, or c) insufficient doping in the p+ $\mathrm{Cu_2O}$ layer. However, we did measure very low contact resistance in the range of (4-35) mΩ cm^2 across the tunnel diode, which was the ultimate goal of the project.

The second part of the thesis deals with development of oxide based absorbers for silicon tandem cells. Low bandgap oxide (and sulfide) semiconductors can absorb solar radiation, and be deposited using low cost methods like PLD, making them interesting as solar absorbers. Here we report $\mathrm{Cu_2V_2O_7}$ as an oxide absorber which has a low bandgap of 2.1 eV. Unfortunately solar cells made with $\mathrm{Cu_2V_2O_7}$ show a very low electrical output: open circuit voltage is only 10 mV. However, the devices do show a photocurrent density of 3.87 $\mathrm{mA/cm^2}$ at 1 V bias, making them interesting as a photosensor. The device performance seems to be limited by the presence of pinholes in the $\mathrm{Cu_2V_2O_7}$ films. Finally we show that the $\mathrm{Cu_2V_2O_7}$ can be sulphurized into $\mathrm{Cu_3VS_4}$ another potential solar absorbing semiconductor.