The preparation and characterization of SnO_x:F/Al_2O_3/Al spectrally selective reflector surfaces for solar concentrator applications

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Abstract

This thesis presents the preparation and characterization of spectrally selective reflector surfaces of pyrolytically deposited fluorine doped tin oxide (SnO_x:F) on aluminum and pre-anodized aluminum. The reflectors are intended for use with silicon solar cells, and good spectrally selective reflector characteristics were achieved with these thinly pre-anodized, fluorine doped tin oxide coated aluminum samples. The aim is to obtain a high solar reflectance for wavelengths below 1.1 µm and low solar reflectance for wavelengths above 1.1 µm, referred to as the cell reflectance (R_{cell}) and the thermal reflectance (R_{therm}), respectively. Thin SnO_x:F films were grown on glass, aluminum and pre-anodized aluminum by spray pyrolysis, while the anodic layers were prepared on aluminum electrochemically using a non-stirred H_2SO_4 bath. A pyrolytically deposited doped tin oxide layer offers spectral selectivity to the aluminum surface. The SnO_x:F films were grown at temperatures between 380 to 450 °C with film thickness varying in the range 200 to 800 nm. X-ray diffraction, atomic force microscopy and scanning electron microscopy have been performed on the tin oxide surfaces and an approximate grain size of 50 to 300 nm is indicated. Hall effect and resistivity measurements were carried out for SnO_x:F films deposited on glass under the same conditions as for those on aluminum. Resistivities in the range 6 to 19 x 10^{-6} Ωm, with carrier concentrations between 1.1 to 5.3 x 10^{20} cm^{-3} and Hall mobilities of 16 to 31 $cm^2V^{-1}s^{-1}$, were obtained using the van der Pauw method. The presence of a thin, 100 to 200 nm thick, interfacial anodic (Al_2O_3) layer is shown to have a strong influence on the optical selective reflectance properties. X-ray diffraction and scanning electron microscopy have also been used to characterize both the anodic and tin oxide films. Solar reflectance calculations were made using the standard AM1.5 solar irradiance spectrum. High solar reflectance is obtained for wavelengths below 1.1 μm and low solar reflectance for wavelengths above 1.1 μm. The best samples had R_{cell} and R_{therm} values of 0.75 and 0.56 respectively for the SnO_x:F/Al film structure and 0.80 and 0.42 respectively for the SnO_x:F/Al_2O_3/Al film structure at near normal angles of incidence. The spectral selectivity is highly dependent on the preparation conditions, doping and thickness of the films. Polarization-dependent angular optical properties of the spectrally selective reflector surfaces are also reported. The angular reflectance measurements were performed using both *s*- and *p*- polarized light in the solar wavelength range (0.3 - 2.5 μm) and revealed strong spectral selectivity. The angular behavior is highly dependent on the polarizing component of the incident beam, the total film thickness and the individual thickness of the Al_2O_3 and SnO_x:F layers. Angular measurements were performed on SnO_x:F/Al_2O_3/Al samples where the anodic Al_2O_3 layers were produced electrochemically and varied between 100 nm to 205 nm in thickness. In this case the SnO_x:F films were grown pyrolytically at a temperature of 400 °C with film thickness varying in the range 180 to 320 nm. Both the angular optical reflectance calculations and experimental measurements show that the cell reflectance is relatively insensitive to the angle of the incident beam, while a low thermal reflectance is maintained up to an angle of about 60 degrees. The conclusion based on the preparation and characterization of SnO_x:F films is that good spectral reflectance selectivity can be achieved using this method and is maintained over a wide range of incident beam angles. The suitability of SnO_x:F/Al_2O_3/Al spectrally selective reflector for application with silicon solar cells is yet to be tested. Further improvements that enhance the cell reflectance are suggested.