SUMMARY

Thin film cadmium telluride (CdTe) photovoltaic (PV) technology offers an effective option for the production of solar electricity owing to lower production costs and increased efficiency of as much as 22 %. Despite the high PV performance of laboratory CdTe solar cells, there are still several technology-related issues such as back-contact strategy, junction activation, and chloride treatment that require better understanding.

$CdCl_2$ activation treatment in the presence of oxygen is a vital step for the production of highly efficient CdTe solar cells. The major issue associated with this treatment step is the difficulty in controlling the concentration of segregated $CdCl_2$ and $CdCl_2{\cdot}2CdO$ residual phases from the GBs and a high Cl concentration (over 10^{19} cm^{-3}) in the CdTe lattice. High concentrations of residuals limit the density of charge carriers in p-type CdTe and cause hygroscopicity of the cells, both of which have a strong impact on cell performance. $CdCl_2$ thermal treatment in N_2-O_2 ambient could be a way to control residuals, thus improving the optoelectronic properties of the CdTe films.

In the present work a systematic study of the influence of different processing variables such as substrate temperature for CdTe deposition and post-deposition $CdCl_2$ activation treatment in air and N_2-O_2 ambient on the properties of CdTe thin films and CdTe/CdS solar cells was carried out, with the aim of understanding the underlying physicochemistry and for optimisation of high efficiency solar cells. CdTe thin films and CdTe/CdS solar cells were prepared by close-spaced sublimation, followed by wet $CdCl_2$ treatment and thermal annealing in air and N_2-O_2 atmosphere at different temperatures. Scanning electron microscopy, energy dispersive X-ray spectroscopy, X-ray diffraction analysis and the Van der Pauw measurements were applied to study the materials, whereas, current – voltage and external quantum efficiency measurements (EQE) were used for cell characterisation.

The structural and morphological properties of CdTe layers deposited on glass and CdS/FTO/glass substrates strongly depended on the CSS substrate temperature. An increase in substrate temperature from 250 to 500°C resulted in increase of CdTe crystallite size from 30 to 140 nm. The subsequent $CdCl_2$ activation in air at 420°C promoted recrystallisation and resulted in equally large CdTe crystallites (145-150 nm), independent of the substrate temperature. Moreover, this activation step implied formation of a $CdTe_{1-x}S_x$ alloy at the CdTe/CdS interface. The extent of recrystallization and intermixing decreases with increase of the substrate temperature from 250 to 500°C, whereas the solar cell efficiency is improved from 2,3 to 10,6 %, respectively.

The influence of $CdCl_2$ thermal annealing in N_2-O_2 ambient on the properties of CdTe films deposited on glass substrates at temperatures of 250°C and 500°C was systematically investigated to follow the formation of p-type conductivity. The $CdCl_2$-activated CdTe films in air at 420°C had high resistivity indicating the high degree of defect compensation. The resistivity of both films systematically decreased in result of $CdCl_2$ thermal annealing in N_2-O_2 ambient from 470 to 600°C. A hole density of ~5×10^{15} cm^{-3} and mobility of 10 $cm^2/V\cdot s$ were achieved for CdTe films as a result of annealing in at 600 °C. A shift of the main (111) peak together with systematic changes in the lattice parameter after each treatment step indicated processes taking place inside the CdTe lattice.

Based on the obtained result, it is claimed that $CdCl_2$ activation induces the formation of melted flux, which promotes CdTe recrystallisation, grain growth and doping with chlorine, and alloy formation at CdTe-CdS interface via mass transport through the liquid phase. The doping density depended on the time, temperature, and initial grain size of the CdTe films, being higher for initially fine-grained material. Changes in the optoelectronic properties of $CdCl_2$-treated CdTe films in N_2-O_2 atmosphere were explained with the removal of chlorine excess from the CdTe lattice. By controlling the thermal annealing conditions, substantial improvement in the optoelectronic properties of CdTe films was achieved. The efficiency of CdTe/CdS solar cells was substantially improved to 14 % by controlled annealing in N_2-O_2 ambient. The EQE showed enhanced response in the long-wavelength region, implying better collection efficiency in CdTe-in good agreement with increased p-type conductivity observed in annealed CdTe films. Although, higher annealing temperatures 500-600 °C improved the electrical properties of CdTe single layers, this approach is not applicable for CdTe/CdS in superstrate configuration but has high perspective for the cells in substrate configuration.