OPTICAL ABSORPTION SPECTRA OF Cu2ZnSn(S,Se)4 THIN FILM SOLAR CELLS BY FOURIER TRANSFORM PHOTOCURRENT SPECTROSCOPY

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In compound thin film solar cells, compound films such as Cu(In,Ga)Se₂ are deposited on metal such as Mo or metal-coated glass substrates. The film quality of the absorber films deposited on metal is different from that deposited on glass substrates. Therefore, optical absorption measurements for compound films within cell structure are necessary. Fourier transform photocurrent spectroscopy (FTPS) is one of measurement methods for optical absorption in lower photon energy region. In this method, optical absorption can be obtained through photocurrent. Therefore, optical absorption of absorber films within cell structure can be measured by FTPS. In this work, we tried to measure optical absorption of Cu₂ZnSn(S,Se)₄ (CZTSSe) within cell structure using FTPS. Change in optical absorption spectra by thermal annealing for CZTSSe solar cells was also studied.

CZTSSe solar cells were used in this study. The solar cell samples were annealed at annealing temperature Tₐ of 520, 540, and 580°C. Optical absorption spectra of CZTSSe solar cells were measured by FTPS. In the FTPS measurement, Fourier Transform InfraRed (FT-IR) spectrometer (Thermofisher Nicolet iS50R) was used as the interferometer and short circuit current was monitored. External quantum efficiency (EQE) spectra of the solar cells were also measured by standard method. Optical absorption is proportional to photocurrent values, i.e. short circuit current value, over the number of incident photons. Optical absorption spectra obtained by FTPS were fitted to EQE spectra to obtain absolute value.

The conversion efficiency increased from 1.20 to 4.57% with increasing Tₐ from 520 to 580°C. Figure 1 shows optical absorption spectra of CZTSSe solar cells. Optical absorption spectra shifted to the lower energy region with increasing Tₐ. This might be corresponding to the change in the band gap energy Eₒ of absorber by increasing Tₐ. The Eₒ was obtained from the EQE spectra. The Eₒ decreased from 1.15 to 0.98eV with increasing Tₐ from 520 to 580°C. In all optical absorption spectra, the Urbach edge was observed. The region called the Urbach edge was characterized by exponential dependence of optical absorption on the photon energy. Urbach energy Eₒ of the absorbers were obtained through the fitting to optical absorption spectra in the region of the Urbach edge. Figure 2 shows the variation of Eₒ as a function of Tₐ. The Eₒ decreased from 25.5 to 23.6eV slightly with increasing Tₐ from 520 to 580°C. Eₒ was assumed to correspond to structural randomness. Therefore, decrease in the Eₒ might be related to improving the crystallinity of absorber by increase in Tₐ.

Based on above results, Evaluation of optical absorption in compound film within cell structure would be possible using FTPS.

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Figure 1: Optical absorption spectra of CZTSSe solar cells annealed at different Tₐ.

Figure 2: Variation of Eₒ as a function of Tₐ.