In this presentation, we demonstrate an optical characterization method that allows the size of microvoid in hydrogenated amorphous silicon (a-Si:H) to be determined readily via spectroscopic ellipsometry. It is known that the volume fraction of the microvoid structure in hydrogenated amorphous silicon (a-Si:H) has a positive correlation with the concentration of Si-H$_2$ bond that relates to the generation of dangling bonds. This leads to the idea that the volume fraction of the microvoid structure becomes a critical factor to deteriorate the photovoltaic performance of a-Si:H/crystalline Si (c-Si) heterojunction solar cells (HJSCs). However, a recent report demonstrates that a-Si:H/c-Si HJSCs prepared using an underdense (void-rich) a-Si:H layer exhibit better photovoltaic performance compared with that using a dense a-Si:H layer; this is caused possibly due to that hydrogen penetration to a-Si:H/c-Si interface suppresses unfavorable heterogeneous epitaxial growth [1]. This indicates that an optimum “moderate void structure” is necessary for a-Si:H/c-Si HJSCs. Recently, we have found that there was a systematic correlation between the void size determined by the positron annihilation method and the optical constant of a-Si:H by spectroscopic ellipsometry [2, 3]. Based on the finding described above, we have developed a characterization method that can readily determine the void size in a-Si:H having the thickness less than 10 nm.

a-Si:H/c-Si heterojunctions were fabricated by depositing 150 nm-thick a-Si:H layers on RCA-cleaned n-type FZ-Si(111) substrates using a standard plasma-enhanced chemical vapor deposition (PECVD). The substrate temperatures ($T_s$) were in the range from 80 ºC to 280 ºC. Based on a correlation between the average void size calculated from the positron annihilation measurement and the optical constants obtained from spectroscopic ellipsometry, performed using a-Si:H layers with the thickness of 150 nm, the average void size was determined for a wide-ranging a-Si:H film thickness of 0.8 to 150 nm.

In Fig. 1, void diameter $D_{\text{void}}$ is plotted as a function of a-Si:H layer thickness $t_{a\text{-Si:H}}$ for $T_s =$ 80, 130 and 180 ºC. $D_{\text{void}}$ steeply decreases in the region of a-Si:H film thickness $t_{a\text{-Si:H}} = 5$ to 10 nm and then converges to a constant value. The $t_{a\text{-Si:H}}$ where $D_{\text{void}}$ converges is generally similar to the minimum film thickness required for the minority carrier lifetime of the a-Si:H/c-Si heterojunction structure to be saturated at a high value.

Fig. 2 shows the correlation between $D_{\text{void}}$ and the infrared absorption peak position wave number on the low wave number side Si-H bond stretching mode (LSM) infrared absorption spectrum obtained by performing peak separation. The shift amount $\Delta k$ of the peak position wave number $k$ can be expressed as $\Delta k \propto -1/(D_{\text{void}}^3)$ [4]. The positive correlation seen in Fig. 2 shows good agreement with the trend represented by the equation described above. This result suggests that Si-H bonds coexist with Si-H$_2$ bonds on the inner surface of the voids.