In silicon hetero-junction (SHJ) solar cells, ultrathin (~10nm-thick) hydrogenated amorphous silicon (a-Si:H) is often used as a passivation layer. This layer passivates the crystalline silicon surface, and also selectively transfers the photo-generated carriers to the external contacts. So, the electronic transport property of this layer is very important. So far, the electronic property is extensively studied for thick a-Si:H, however, it is not well studied for ultrathin films. In this presentation, we show the electronic property for ultrathin a-Si:H films, and discuss the carrier transport and trapping.

We characterized the electronic property of ultrathin a-Si:H layer, using two methods: widely used constant photocurrent measurement (CPM) technique and recently developed optical pump-probe (PP) technique [1]. From CPM, we obtained the valence band tail distribution and the deep-level defect absorption at 1.37 eV. The Urbach energy is determined from the valence band tail slope. From the PP experiments, we evaluated carrier (electron) transport and trapping at the conduction band tail. The a-Si:H films we characterized in this study were prepared on glass substrates, by means of plasma enhanced chemical vapor deposition operated at 60 MHz discharge of silane and hydrogen gas mixture. The growth conditions are following: the growth temperatures of 80–240 °C, the hydrogen dilution of up to 20, the film thickness from d = 4 to 220 nm.

Figure 1 shows the thickness dependence of the electronic properties of a-Si:H prepared at 160°C [2]. It is clearly shown that the bandgap, $E_g$, is widened for ultrathin a-Si:H of 4 nm (Fig.1 (a)). Except for the ultrathin a-Si:H, the bandgap stays roughly constant of $E_g = 1.73$ eV. It is also shown that the refractive index, $n_{520}$, at 520 nm is strongly reduced for the ultrathin films, indicating the formation of less-dense materials. Our finding in this study is that the gap state parameters of Urbach energy, $E_U$, deep-level absorption, $\alpha_{1.37eV}$, and trapped carrier (electron) density, $n_v$, are all increased if $d$ is decreased smaller than ~10 nm, as shown in Fig. 1(b) and (c). These parameters are varied from $E_U$ ~ 60 meV, $\alpha_{1.37eV}$ ~ 15 cm$^{-1}$, and $n_v/n_i$ ~ 4 x 10$^{-5}$ for thick a-Si:H of $d$ = 130 nm to $E_U$ ~ 135 meV, $\alpha_{1.37eV}$ ~ 200 cm$^{-1}$, and $n_v/n_i$ ~ 2 x 10$^{-5}$ for ultrathin a-Si:H of $d$ = 4 nm. Thus, $E_U$ is roughly doubled, and both $\alpha_{1.37eV}$ and $n_v/n_i$ are increased by one order of magnitude. Such increases in $E_U$ and $n_v/n_i$ suggests the enhancement of carrier trapping due to the broadening of the band tail. The increase in $\alpha_{1.37eV}$ indicates the formation of more deep-level defects for ultrathin a-Si:H. The details on experimental data and discussion will be given in the presentation.

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References

Figure 1: Thickness, $d$-dependence of electronic properties of a-Si:H, prepared at 160 °C. (a) Bandgap, $E_g$, and refractive index, $n_{520}$, a, determined from spectroscopic ellipsometry. (b) Urbach energy, $E_U$, and deep-level defect absorption, $\alpha_{1.37eV}$, obtained from CPM. (c) Photocurrent, $I_p$, trap associated current, $I_t$, and trapped electron density, $n_v/n_i$, obtained in PP experiments. Here, $n_i$ is the valence electron density.