IMPACT OF WAFER THICKNESS ON A-Si:H/C-Si HETEROJUNCTION SOLAR CELLS

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In crystalline silicon (c-Si) solar cells, it is expected that the thickness of c-Si wafers is steadily decreased from the current industrial standard of 180 μm down to 100 μm, for reducing the material cost. The reduction in wafer thickness is also beneficial to enhance the conversion efficiency, supposed that all of the bulk material quality, surface passivation, and light management are well accomplished simultaneously. According to Richters' work [1], a theoretical limit efficiency of 29.4% is expected to be obtained with a wafer thickness of 110 μm, which is much thinner than the current industrial standard. Since the limit efficiency depends only weakly on the wafer thickness near the peak, a relatively high efficiency is still achievable with much smaller wafer thicknesses down to 30 μm. Of course, going to thinner wafers beyond a certain limit will require an advanced concept for module assembly and not easily accepted in industry. Nevertheless, it is of fundamental importance to explore the potential of c-Si solar cells using thin or very thin wafers. The scope of this work is to examine the potential of very thin c-Si solar cells experimentally, especially with a-Si:H/c-Si heterojunction (SHJ), from the optical and electrical points of view.

First, the potential of light absorption within thin Si wafers was examined with a dummy cell structure which is a pyramidally textured wafer with a dielectric anti-reflection coating and a back reflector. Optical characterization clarified that an efficient quasi-Lambertian light absorption is achievable in a very wide range of wafer thicknesses from 30 to 400 μm as shown in Fig. 1, where the short circuit current densities expected from the absorption spectra were plotted as implied J_{SC} (iJ_{SC}). Second, the potential of open circuit voltage in thin c-Si solar cells was investigated via implied V_{OC} (iV_{OC}) measurement of n-type textured Si wafers (<100>, n-type, ~3 Ωcm) passivated with intrinsic a-Si:H films grown with PECVD. A monotonic and steep increase in iV_{OC} with decreasing the thickness was experimentally confirmed in a wide range of wafer thickness from 30 to 400 μm, as shown in Fig. 2. A notably high iV_{OC} of 0.763 V was obtained with a 32-μm-thick wafer. The optimum wafer thickness for the best efficiency was estimated using the iJ_{SC} and iV_{OC}, and found to be approximately 100 μm, which is slightly thinner but still in good agreement with the predicted value from the theory [1]. A very thin SHJ solar cell with a thickness of 59 μm was also developed. As a result, a conversion efficiency of 20.6% was obtained, which was almost the same as that (20.9%) of the monitor cell with a 180-μm-thick wafer. The trade-off relationship between J_{SC} and V_{OC} was also clearly observed, as expected. These results indicate that the high potential of very thin c-Si cells. [1] A. Richter et al., IEEE JPV vol.3, 1184 (2013).

Fig. 1. Implied (expected) J_{SC} calculated from the optical absorptance spectra obtained using dummy cell structures: AR film/SiNx/c-Si/SiNx/back reflector. Several J_{SC} in the high-efficiency c-Si cells

Fig. 2. Measured implied V_{OC} of (ia-Si:H/c-Si/(ia-Si:H structures as functions of wafer thickness (symbol). Solid line shows calculated V_{OC} variations against wafer thickness, assuming a bulk lifetime of 3 ms and a surface saturation current density of 1.8 fA/cm².