Area 7: Performance and Reliability of PV Modules

J_{SC} AND V_{OC} REDUCTIONS IN SILICON HETEROJUNCTION PHOTOVOLTAIC MODULES BY POTENTIAL-INDUCED DEGRADATION TESTS

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Si heterojunction (SHJ) photovoltaic (PV) modules have attracted a great deal of interest because of their performance superiority [1]. Although the SHJ PV modules have been already commercialized, the understanding of their long-term reliability seems to be insufficient. We have thus far investigated the potential-induced degradation (PID), performance deterioration of PV modules triggered by a bias between a module frame and cells, of SHJ PV modules, and observed a reduction in short-circuit current density (J_{sc}) alone [2]. The emergence of optical loss is strongly indicated as the cause of J_{sc} reduction. In this study, we have performed the detailed analysis of cell materials aiming at the clarification of the cause of the optical loss induced by a PID test. We have also conducted further long-duration PID tests of the SHJ PV modules to elucidate whether other degradation behaviors occur.

We fabricated one-cell modules using tempered white cover glass, ethylene-vinyl acetate copolymer (EVA), and a polyvinyl fluoride (PVF)/polyethylene terephthalate (PET)/PVF backsheet. PID tests were performed by applying a negative bias of −2000 V to an SHJ cell with respect to an Al plate placed on the surface of the module cover glass at 85 °C with unintentional humidity control (<2%RH).

Figure 1 shows the In K-edge X-ray absorption near edge structure (XANES) spectra of W-doped In oxide (IWO) layers on SHJ cells before and after the PID test for 53 days. The spectra of In metal and In_2O_3 are also shown as references. The spectrum of the IWO film before PID well overlaps with the reference In_2O_3 spectrum, while the spectrum of the IWO film significantly changes after the PID test. Fitting analysis using the In and In_2O_3 reference spectra revealed that ~24% of In atoms exist as In metal after the PID test, meaning that In atoms in the IWO film are partly reduced. This may deteriorate the transparency of the IWO film and can thus be the cause of optical loss in SHJ PV modules induced by a PID test. We have confirmed, by secondary ion mass spectrometry (SIMS) measurement, that Na atoms on the order of 10^{21} $cm^{-3}$are introduced into the IWO film during the PID test. The Na atoms may induce the reduction of In atoms.

Figure 2 shows the normalized open-circuit voltage (V_{oc}) of SHJ PV modules as a function of PID-stress duration. We have newly discovered that the V_{oc} of SHJ PV modules starts to decrease at a PID duration of ~30 days. This is probably because Na atoms invading into SHJ cells act as recombination centers for minority carriers. We have actually confirmed the invasion of Na atoms on the order of 10^{22} cm^{-3} into SHJ cells by SIMS measurement.

Finally, we emphasize that the PID condition and duration used in this study are considerably severe, and SHJ PV modules have markedly high tolerance for PID.

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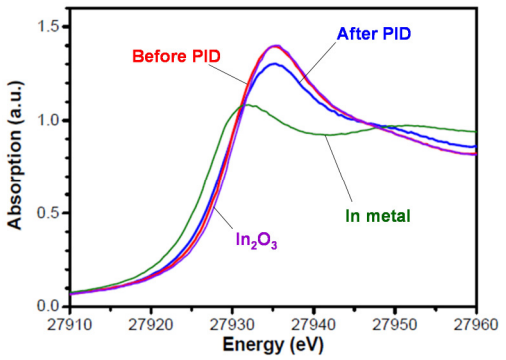

Figure 1: In K-edge XANES spectra of IWO films on SHJ cells before and after the PID test.

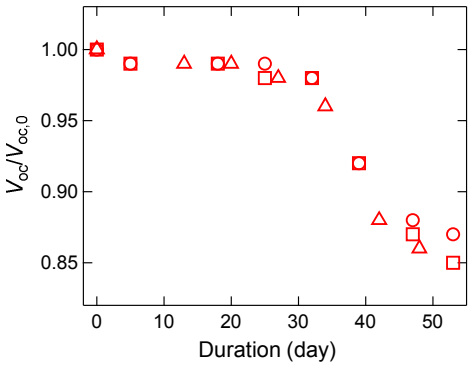

Figure 2: Normalized V_{oc} of SHJ PV modules as a function of PID-stress duration.

References

[1] M. Taguchi et al., IEEE J. Photovoltaics **4**, 96 (2014).
[2] S. Yamaguchi et al., Sol. Energy Mater. Sol. Cells **161**, 439 (2017).