Carrier Collection Efficiency for Multiple Quantum Well Solar Cells under High Sunlight Concentration

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For a solar cell including multiple quantum wells (MQWs), it is expected that charge accumulation in the wells induces band bending and degrades the efficiency of carrier collection when the photo-generation of carriers is rapid, i.e., under strong sunlight irradiation. We therefore developed a setup to measure carrier collection efficiency (CCE) for a monochromatic probe light under strong white bias light. Here, both probe AC laser light (532 or 940 nm) and DC white bias light (up to 400 suns) were irradiated on a cell simultaneously and the AC component of the photocurrent was detected as the one generated by the monochromatic probe light. The probe intensity was approximately 1000 times lower than the DC bias so that the probe light never affects the charge accumulation in the wells. CCE was evaluated as the ratio between the monochromatic photocurrent at a given bias to the saturation value at a large reverse bias assuming 100% efficient carrier collection at that reverse bias.

When a significant band bending emerges in the intrinsic region where MQWs exist, CCE will degrade. Since the probe light is absorbed in a different position of a cell according to the wavelength (Fig. 1), the difference in the degradation behavior with respect to the probe wavelength will tell us how the band is bent. The extent of band bending may depend on the barrier thickness owing to the tunneling-assisted carrier transport for thin barriers alone, we investigated InGaAs/GaAs/ GaAsP MQW cells with barrier of 2, 3, 4, 5 and 6 nm as well as a GaAs reference cell. CCE under 400-sun illumination in Fig.2 show the large degradation for 532 nm as compared with 940 nm. This results indicate the flat-band situation in the vicinity of p-region induced by electron accumulation as shown in Fig.3. However, CCE can be improved sufficiently by tunneling effect when the barrier thickness decreased.

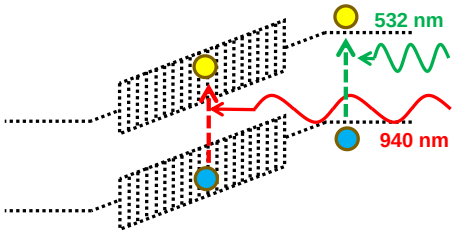


Fig.1 Position of carrier generation by 532- and 940-nm monochromatic excitation

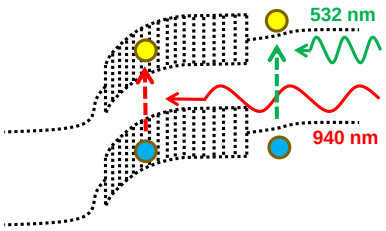
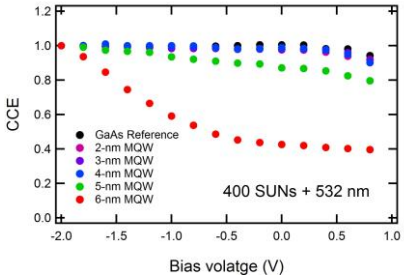


Fig.3 Band bending due to carrier accumulation in 6-nm MQW under high concentration



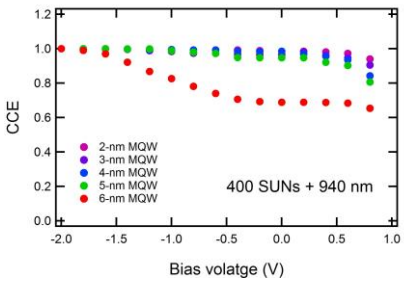


Fig.2 CCE under 400 suns with 532 and 940-nm monochromatic light