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Coupling effects in multijunction solar cells

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Simple model of multijunction solar cells consider that the open circuit voltage V_{oc} of multijunction equals to the sum of each sub-cells while the short circuit current I_{sc} of multijunction solar cells depends on the minimum one of sub-cells. However, the relationship is only true under many restrictions such as the *I-V* of sub-cell is independent with each other. Many factors could lead to the deviation of the relation V_{oc}=sum $\{V_{oc,i}\}$ I_{sc}=min$\{I_{sc,i}\}$, such as luminescence coupling and low shunt resistance. Luminescence coupling is related to the radiative recombination in sub-cells. Secondary photons cause the improvement of current of the sub-cell below, which may change the current-limiting junction. The effect of luminescence coupling could be observed from EQE artifacts. EQE artifacts appear both between GaInP/GaAs and GaAs/Ge in GaInP/GaAs/Ge solar cells. After 1 MeV electron irradiation, EQE artifacts in GaInP/GaAs and GaAs/Ge declined, which may due to the serious decay of internal luminescence efficiency that depends on material quality and density of defects. As GaInP is under quasi-open circuit condition when artifacts in GaAs is measured, the decrease of artifacts could reflect both the decreases of open circuit voltage of GaInP sub-cell and the increase of SRH recombination current. Protons generate much larger number of defects in GaInP compared with electrons. From mapping of EQE in partial irradiated samples, the two-dimension behavior of artifacts was also studied. Lateral scanning of the partial damaged samples show a smooth artifacts transition region that appears near the boundary of damaged region in MJ solar cells. This is found correlated to the difference in the lighted areas of bias light and EQE pulse spot. Two-dimensional artifacts analysis could properly explain the smoothness and shift of damage interface. Low parallel resistance could also affect coupling between junctions as well as EQE measurement results. Low parallel resistance of sub-cell causes the low equivalent shunt resistance or “knee” in *I-V* curve of a multijunction solar cell, resulting in decline of fill factor. The parallel resistance of the sub-cell may due to dislocations or other macro-defects that are generated during initial growth or the damage in subsequent use. GaInP/GaAs/Ge solar cells were irradiated by 50 keV, 70 keV and 150 keV protons. The EQE artifact of GaInP in 700~750 nm increases after irradiation, which may attribute to the parallel resistance in GaInP. However, these artifacts exhibit a special energy correlation, i.e., the artifacts that caused by the 70 keV proton is more obvious, indicating that the appearance of the artifacts is closely related to the damage in the junction region. The phenomenon is simulated by one dimensional numerical calculation that based on a defect-assisted across junction recombination model. From calculation, one could get that such parallel shunt resistance is related to the width of space charge region. Coupling in sub-cells is a key factor that should be taken into consideration when a new type of multijunction solar cells are designed or optimized. The text of the abstract starts here.

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References

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