SOUTENANCE DE THESE

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Irradiation effects in GaInP/GaAs/Ge triple junction solar cells for deep space applications

This thesis is the result of work on the irradiation effect of lattice matched GaInP/GaAs/Ge triple junction (TJ) solar cells in LILT conditions. Initiated by needs of the understanding of EOL performances of the solar cells during the JUICE mission, we have found very peculiar phenomena which are not supposed to occur if it was irradiated at room temperature.

1) The electron and the proton seem to induce degradations in TJ cells in different ways in LILT condition. We have observed in general a larger degradation of FF and P_{MAX} from electron irradiated TJ cells compared to proton irradiated ones. This distinct difference has originated especially from the top and bottom sub-cells due to the occurrence of excess dark current. This additional current in dark seems to be related to the indirect tunneling effect by defects induced by electron irradiation. Furthermore, EOL FF and P_{MAX} appeared to be more and more spread from cell to cell as the electron fluence increased. The large distribution of EOL P_{MAX} of TJ cells implies that the worst performance must be considered as a value for the mission.

2) Individual analysis of proton irradiated component cells revealed that the electric field dependence of the recombination current of EOL TJ cells in LILT condition mostly originated from the top and the middle sub-cells. The contribution of this recombination current on the total degradation of P_{MAX} in LILT condition is much larger than the case of room temperature.

3) Proton irradiated bottom component cells exhibited a larger drop of I_{SC} at a lower temperature, which potentially proposes a current limiting by the bottom sub-cell in the TJ structure. A temperature dependence of RF(I_{SC}) recovery by an isochronal annealing and the orientation dependence of I_{SC} degradation of the bottom component cell support that its degradation mechanism could be related to defect clusters formed along proton tracks, acting like insulating (non-active) area for minority carriers.

Overall, exposed in 1 MeV proton environment in LILT condition, the degradation of TJ cells is more or less equally contributed by all sub-cells. However, it should be noted that the damage induced by proton in a TJ structure is rather complex. The higher the proton energy is applied, the deeper the penetration depth is. Furthermore, the energy loss per unit length of proton will be smaller at higher energy ranges, resulting in a less degradation of the upper cells. On the other hand, the electron with the higher energy can simply produce more defects through its trajectory. This difference in the TJ structure complicates the qualitative analysis of electron and proton irradiation of the TJ cell in LILT condition. Therefore, to complete a modeling of the GaInP/GaAs/Ge TJ solar cell degradation in LILT condition, additional irradiation tests with different energies must be conducted.

Key words: solar cells, irradiation, radiation induced defects, annealing, tunneling, LILT

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