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Luminescence Analysis of Radiative and Nonradiative Recombination in Si Solar Cells

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Abstract:

Processes of radiative and nonradiative recombination of charge carriers play a key role in solar cell (SC) structures. It was considered that a dominant mechanism of intrinsic radiative recombination (so-called, near-band-edge recombination, NBE) in Si is bimolecular recombination of electrons and holes at T > 100 K. The purpose of my paper is to review our results concerning the radiative and nonradiative recombination in Si-based SC structures at room temperature (RT).

Experimental Si SC structures were fabricated by ion implantation, diffusion, and vapor-phase epitaxy techniques. A detailed description of their technology and characteristics as well as electroluminescence (EL) measurement conditions can be found in [1]. To reveal the radiative and nonradiative mechanisms in SCs at RT, we have studied current dependency of an integrated EL intensity, EL decay kinetics after the SC turn-off and EL spectra over a wide range of currents (I) through the p-n junction.

Behavior of current dependency of the integrated EL intensity is linear at $I < I_{thr}$ and sublinear at $I > I_{thr}$. The kinetics of the EL decay measured at $I < I_{thr}$ is charaterized by the current-independent decay time constant. To reveal the dominant mechanism of RT radiative recombination in Si SCs, we used the technique suggested in [2]. We have revealed that the exciton recombination involving one and two optical phonons is dominant in Si SCs at RT. We have also found that the decay time constant is equal to the minority carrier lifetime. It means that the Shockley–Read–Hall mechanism governs nonradiative recombination.

At $I > I_{thr}$, there are no changes in the EL spectra. Such behavior of the EL spectra shows that the sublinear integrated EL is unrelated to the change in the radiative recombination mechanism. The EL decay kinetics after the SC turn-off for the current $I > I_{thr}$ is characterized by a faster initial decrease in the EL intensity and an exponential decay at the same time constant for longer times. The sublinear integrated EL dependence and its fast decay after the diode turn-off at $I > I_{thr}$, are associated with an additional mechanism of nonradiative recombination parallel to the Shockley-Read-Hall process. Our estimations indicated the presence of Auger recombination.

References

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2. J.R. Haynes, M. Lax, W.F. Flood, “Analysis of intrinsic recombination radiation from silicon and germanium”, J. Phys. Chem. Solids, **8**, 392-396 (1959).