# An investigation of the recombination processes in $InAs/GaAs_{1-x}Sb_x$ quantum dot solar cells

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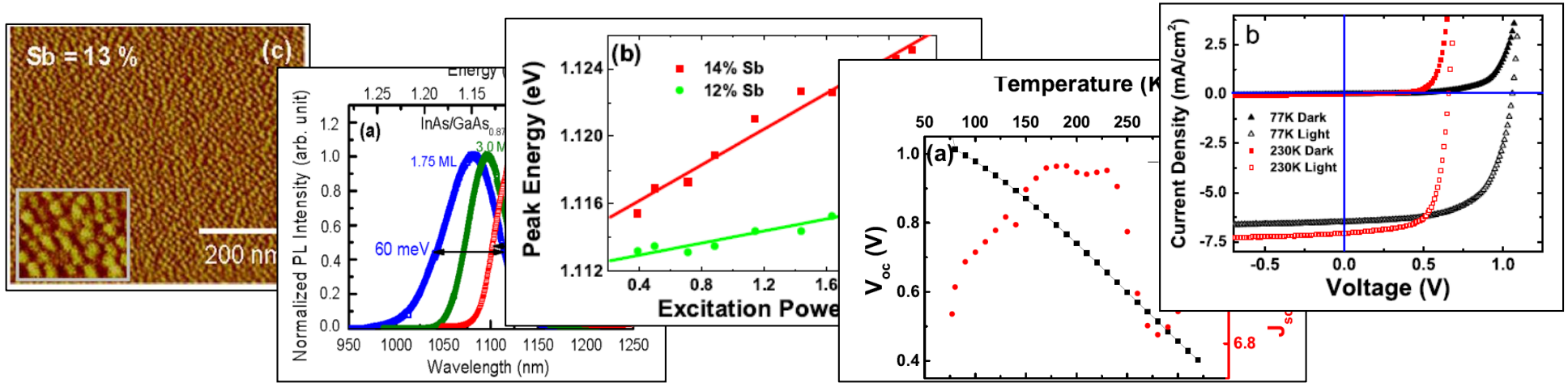


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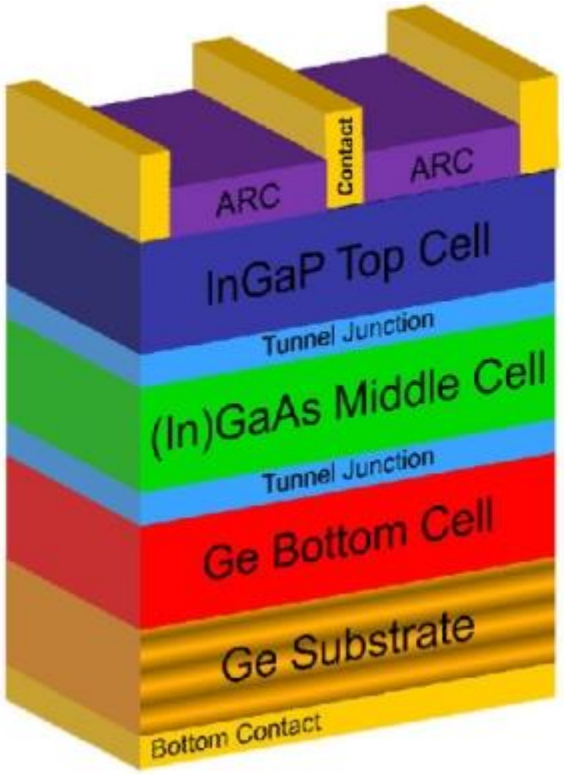
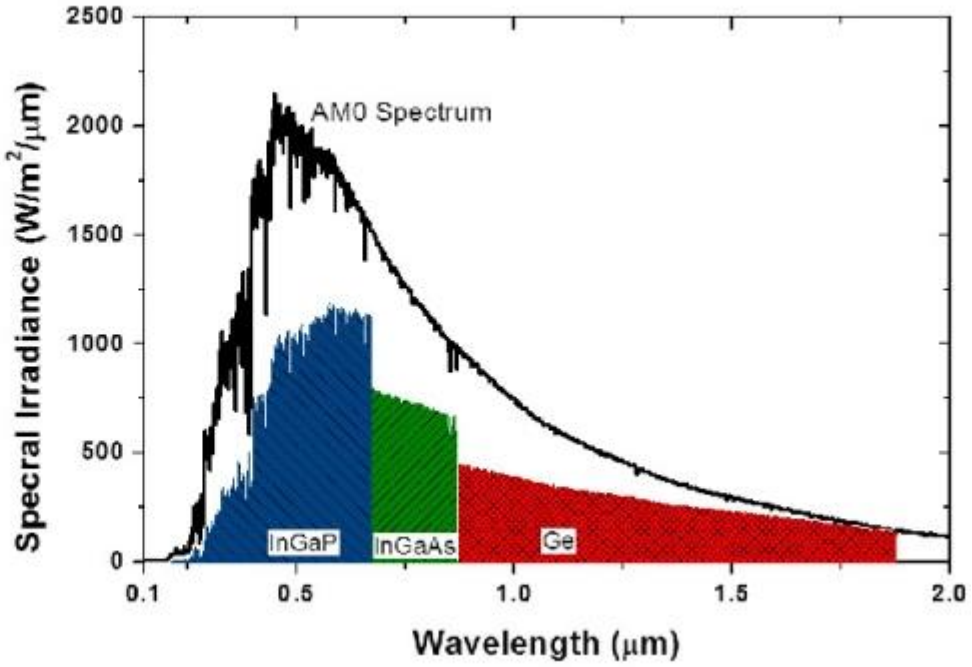
# Introduction

## Multi-junction solar cell

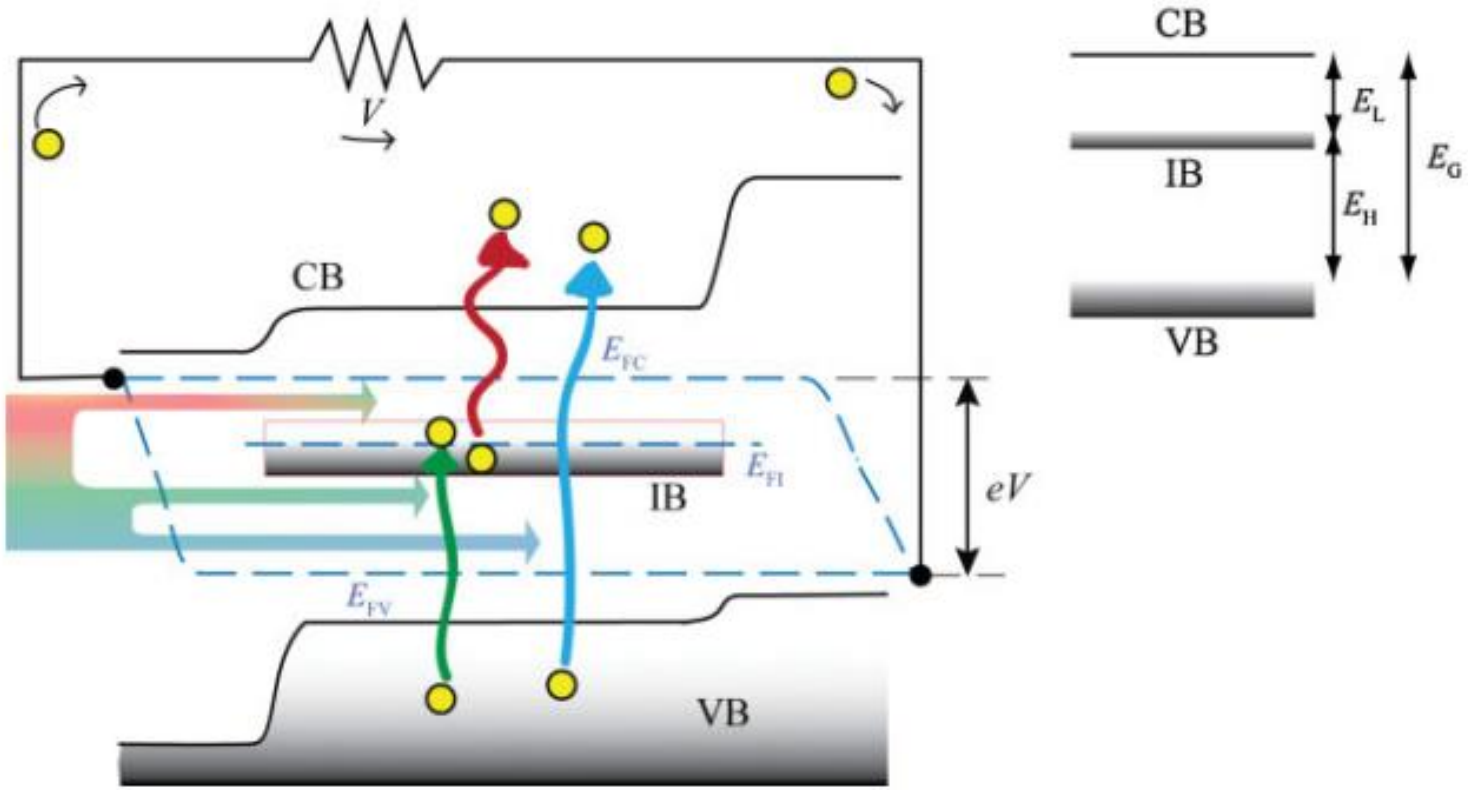



Forbes, David, and Seth Hubbard. "Solar-cell-efficiency enhancement using nanostructures." SPIE Newsroom (2010).

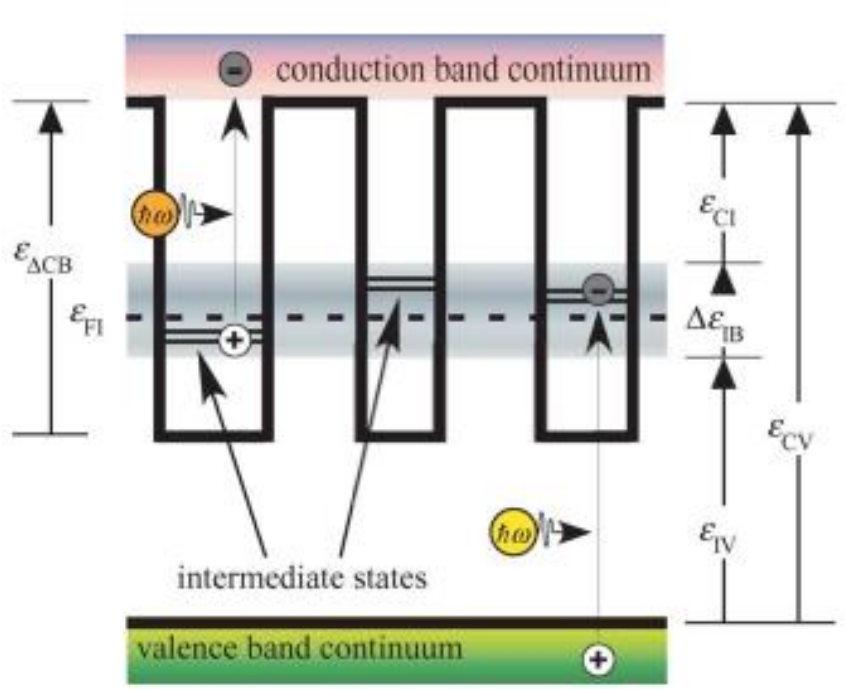
# Introduction

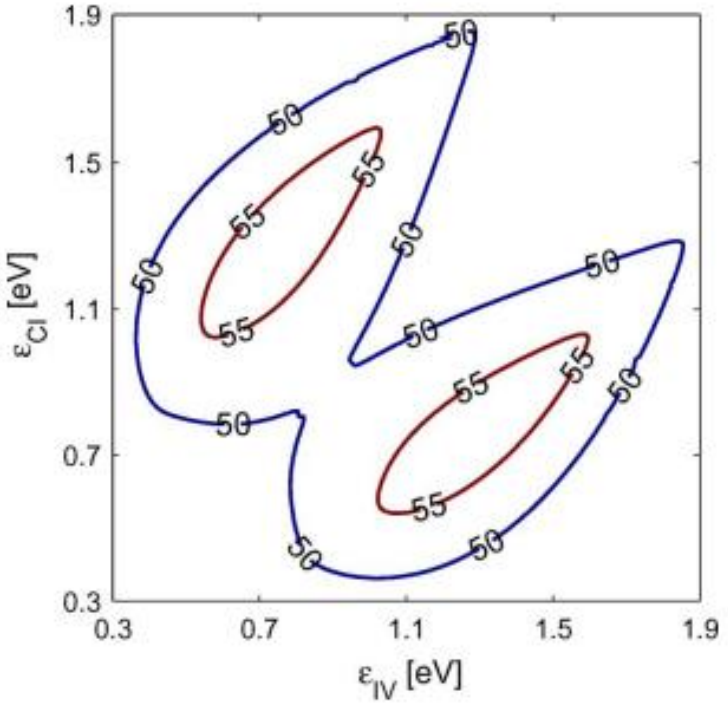
## Intermediate Band Solar Cell Band Diagram




Luque, A. and Martí, A. (2010), The Intermediate Band Solar Cell: Progress Toward the Realization of an Attractive Concept. Adv. Mater., 22: 160–174.

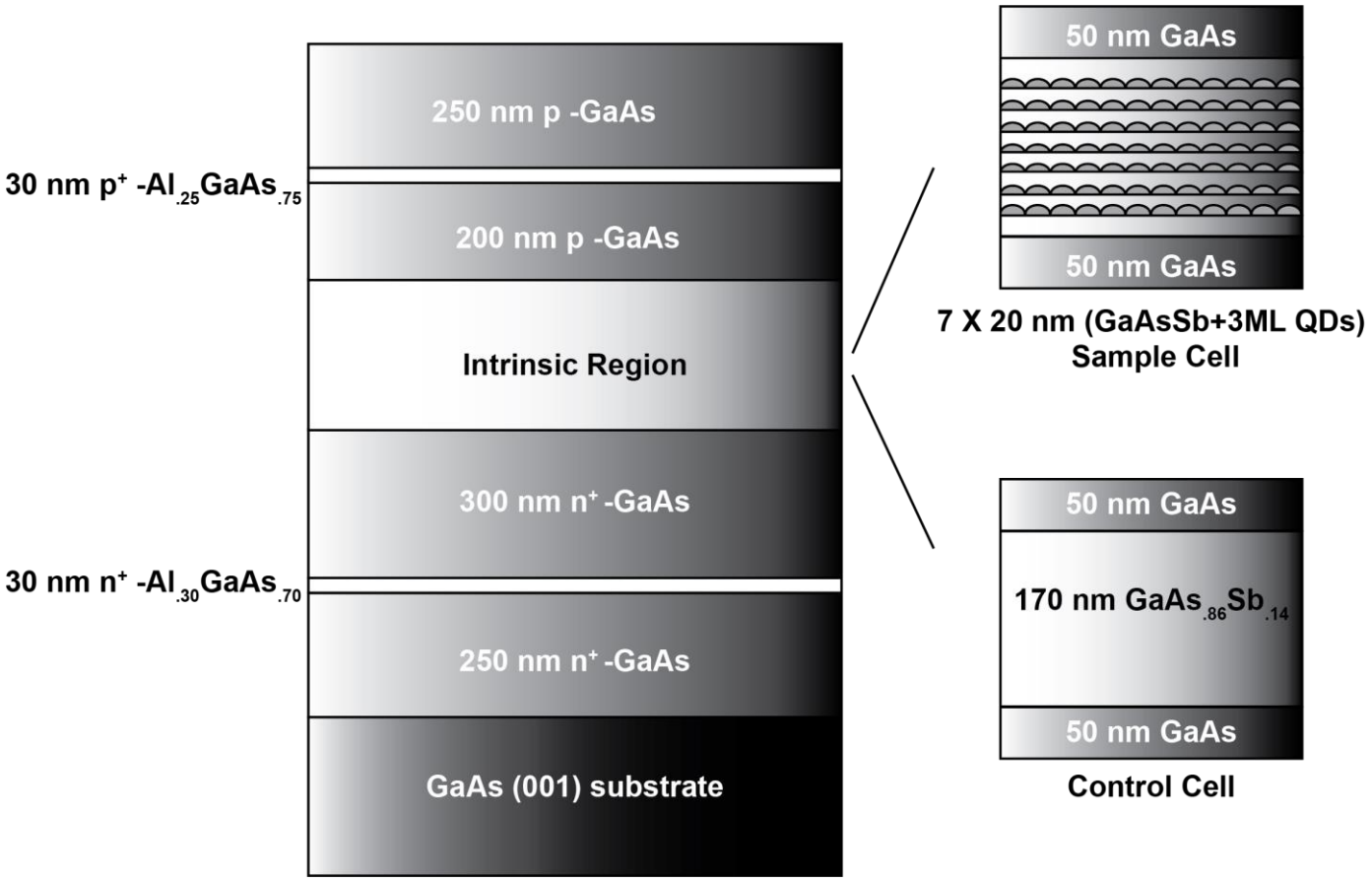
# InAs/GaAsSb QDs for Intermediate Band Solar Cell application




- Levy, Michael Y., and Christiana Honsberg. "Nanostructured absorbers for multiple transition solar cells." IEEE Transactions on Electron Devices 55.3 (2008): 706-711.

# Sample Structure




- Two different intrinsic region designs;
- QD cell: 7 x 20 nm ($GaAs_{0.86}Sb_{0.14}$ + 3ML QDs) + 30 nm GaAsSb cap sandwiched by 50 nm GaAs.
- Control cell: 170 nm GaAsSb sandwiched by 50 nm GaAs;

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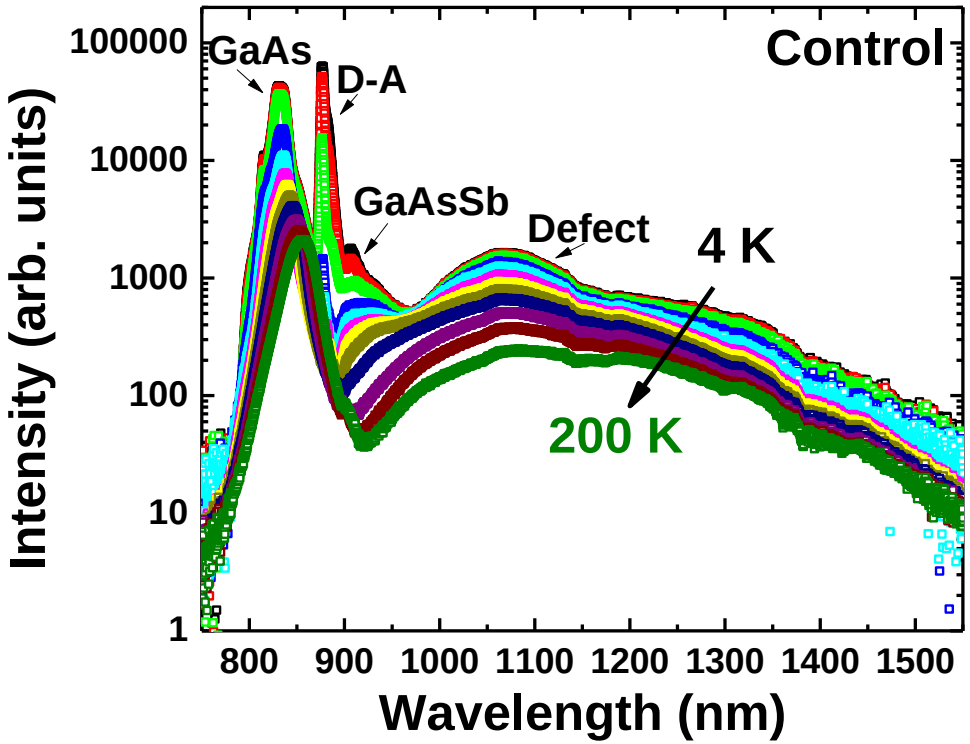
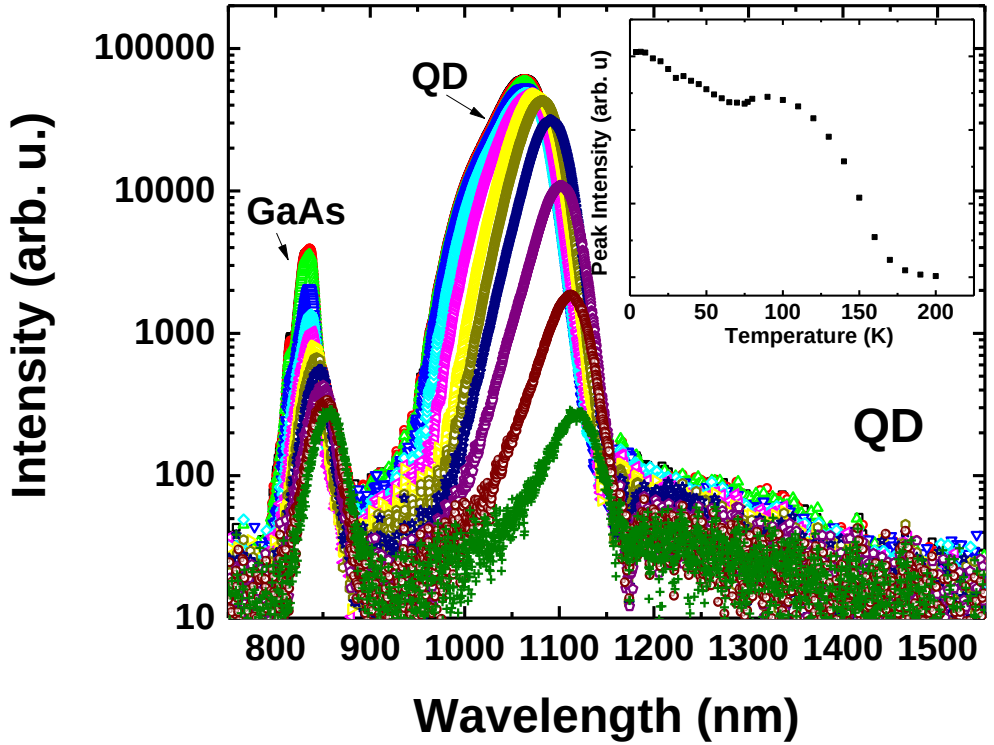
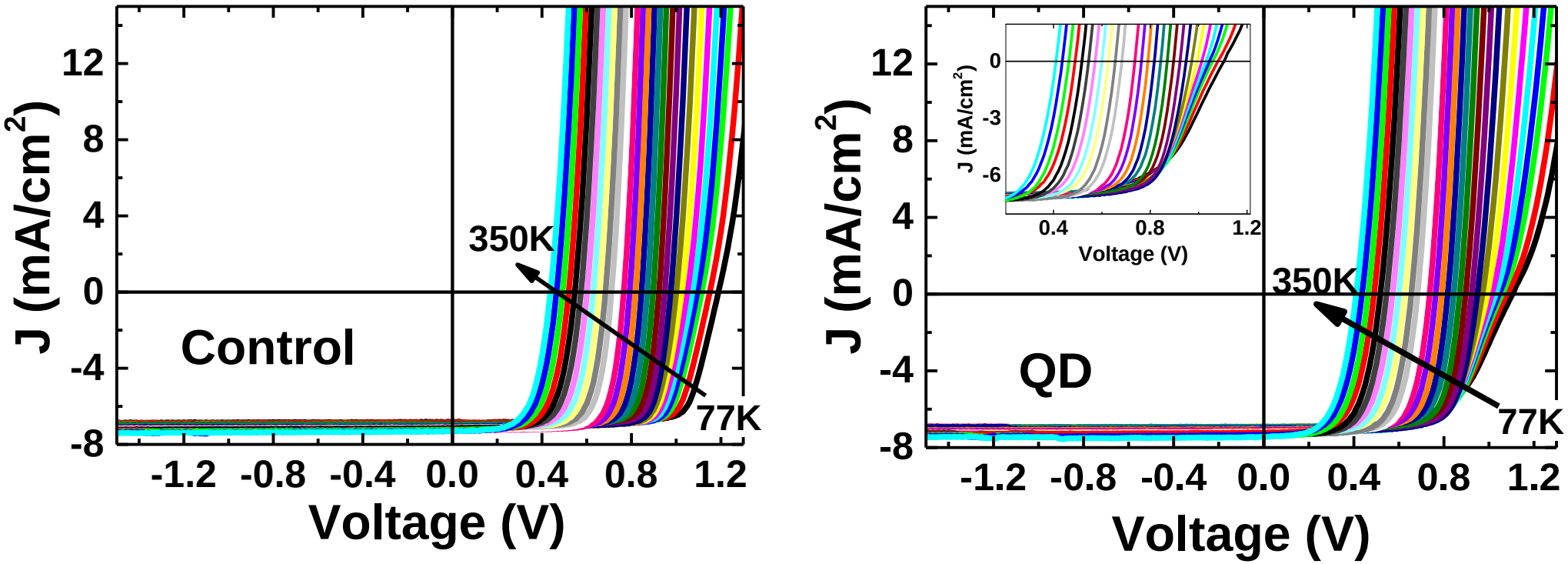
# Temperature Dependent Photoluminescence



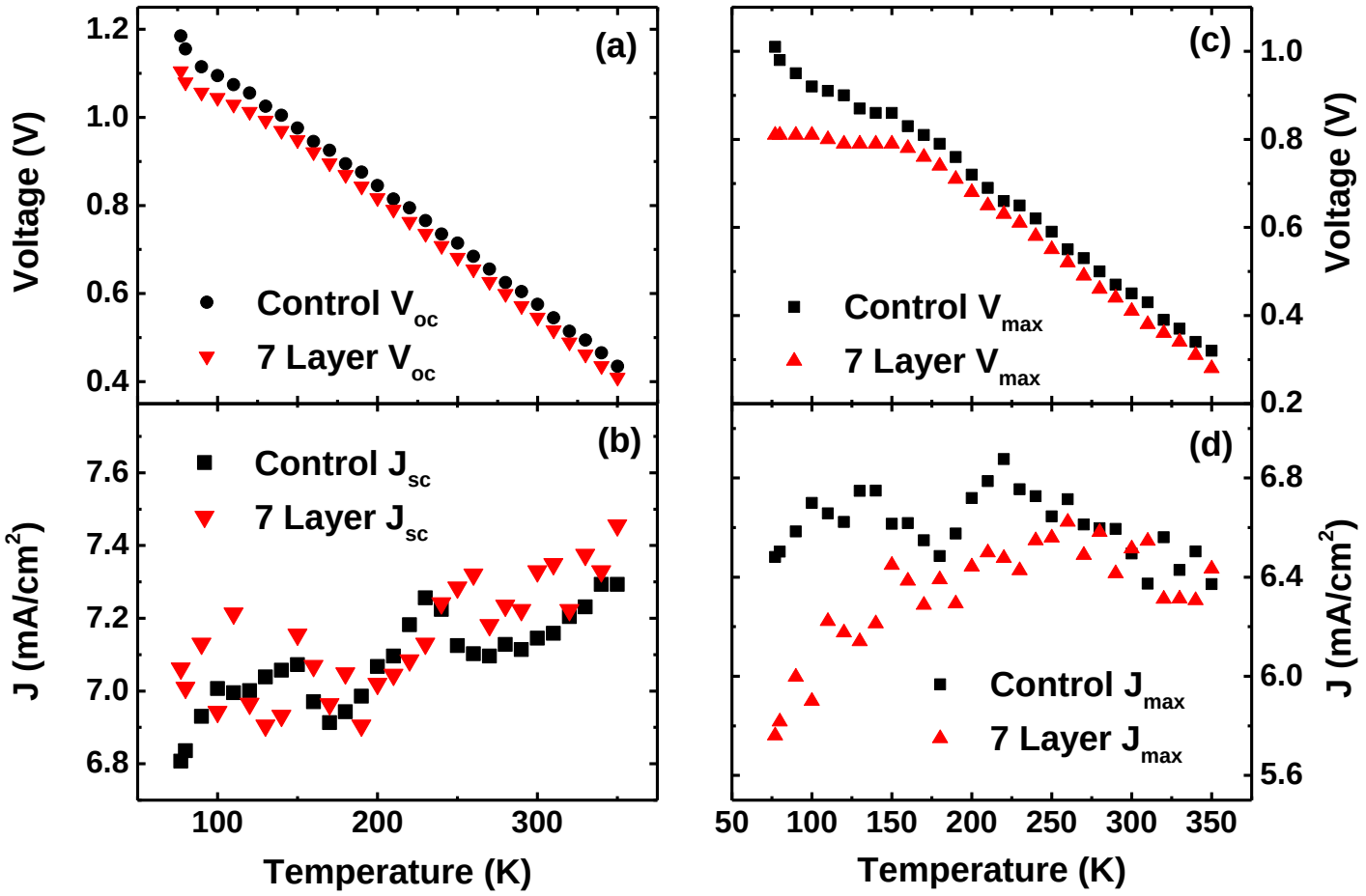

- Multiple transition observed;
- Multimodality behavior is found in QD cell;
- Noticeable defect band in QD cell above 200 K.

# Current-Voltage vs Temperature




- Massive $V_{oc}$ reduction in both control and QD cells
- Series resistance and the QD inhomogeneity (0.8 - 1.0 V) found in QD cell at low temperature.

# Current-Voltage vs Temperature




- Usually large reduction of $V_{oc}$.
- Unusual $J_{sc}$ behavior;
- PCE degradation above 150 K

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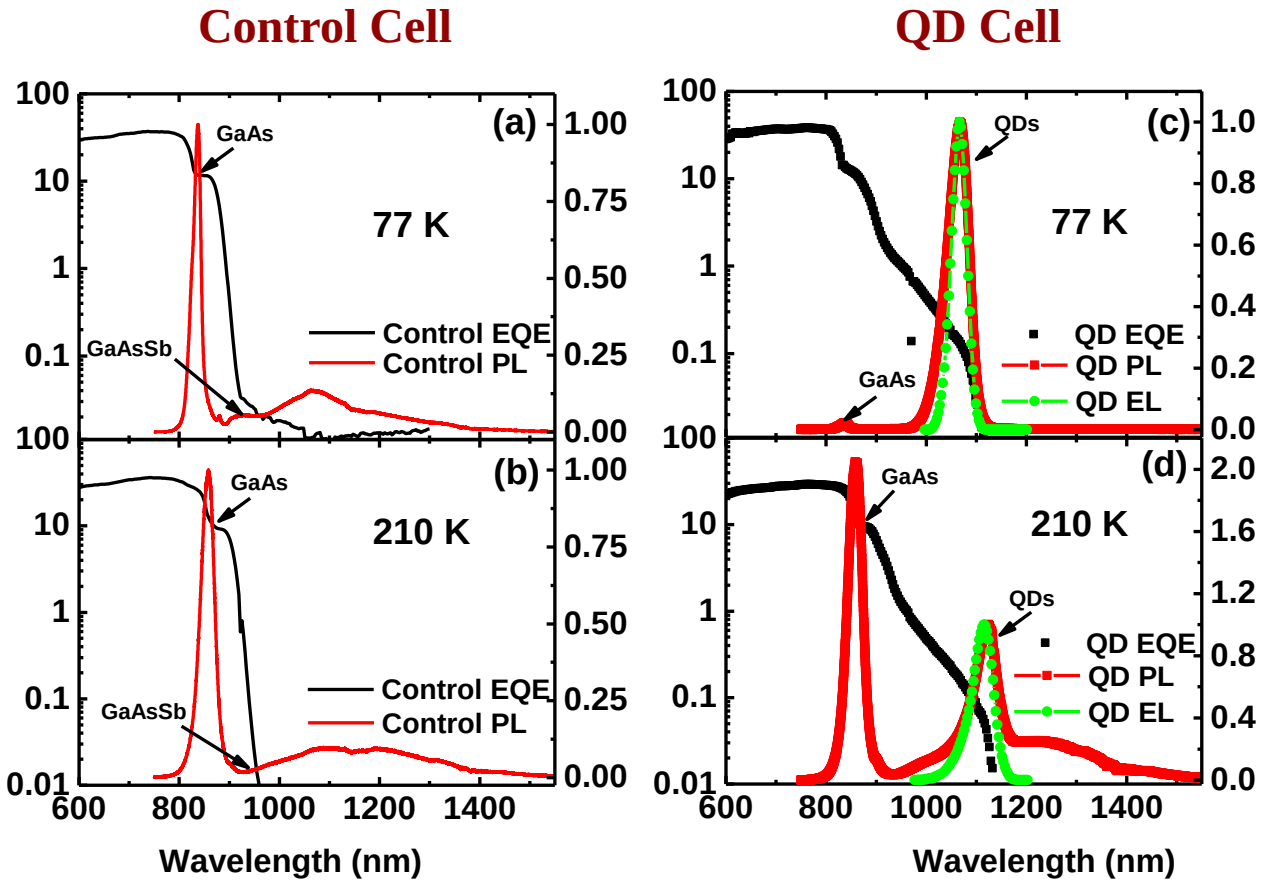
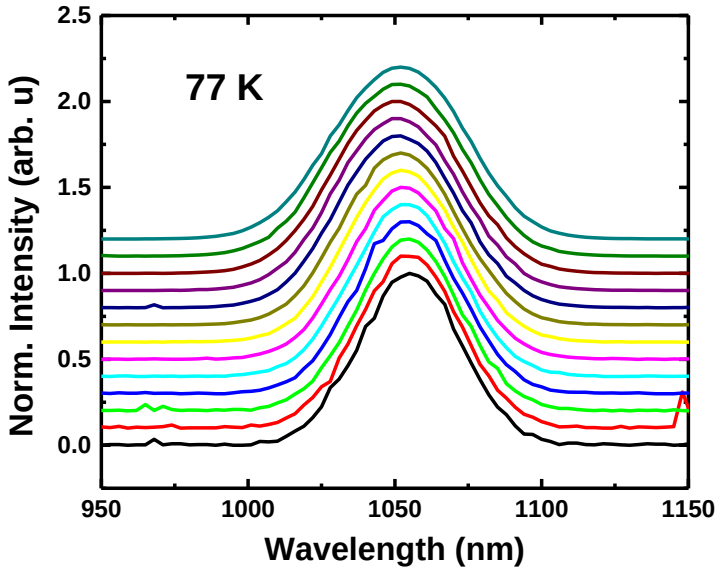
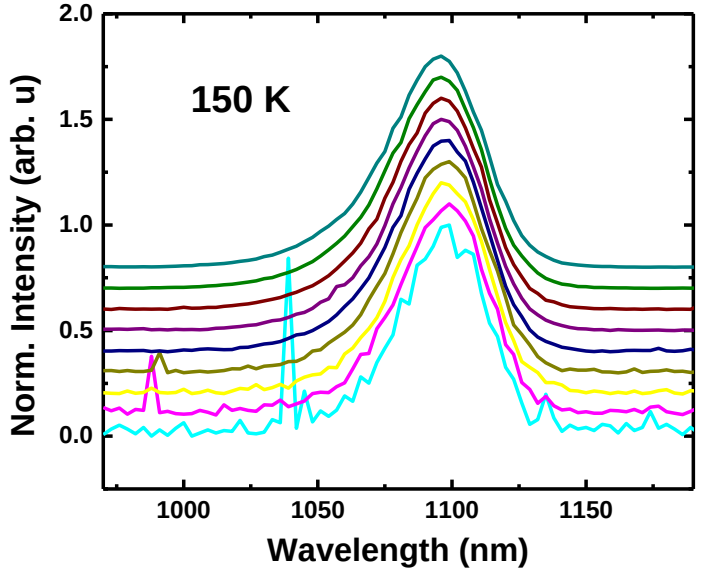
# Comparison of Recombination and Carrier Extraction

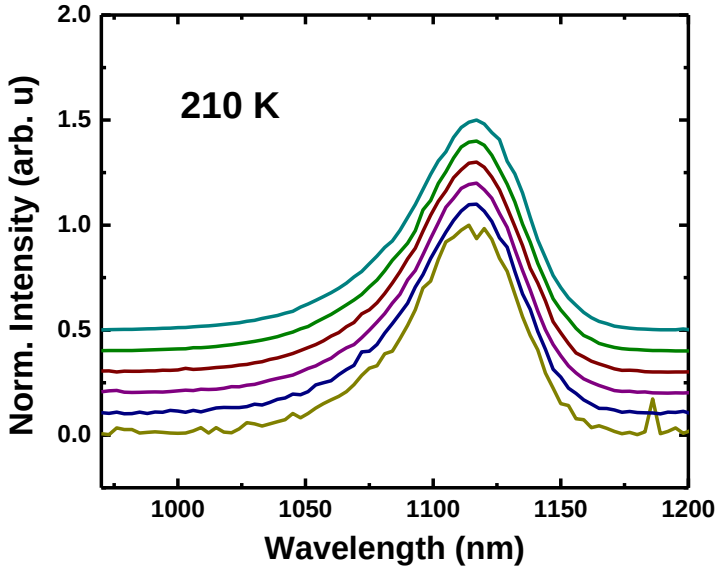


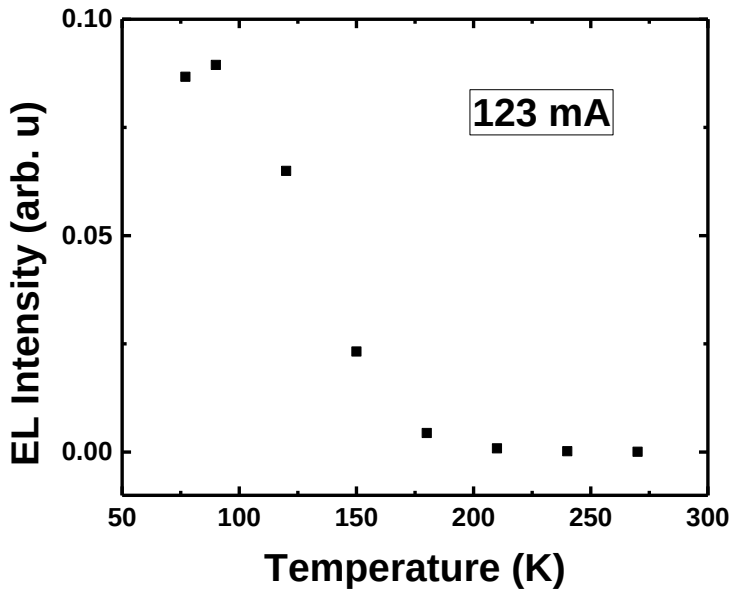

- Enhanced photocurrent due to QD transition;
- Dramatical reduction of PL and EL intensity at 210 K;
- Evident broad defect band at 210 K.

# Temperature Dependent Electroluminescence



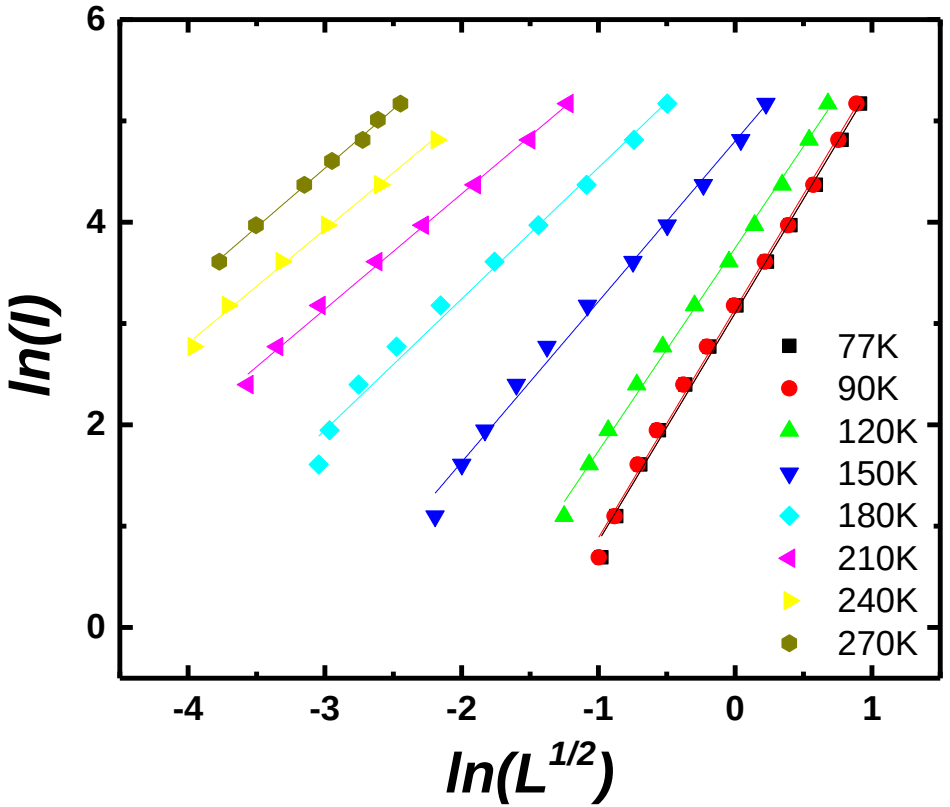



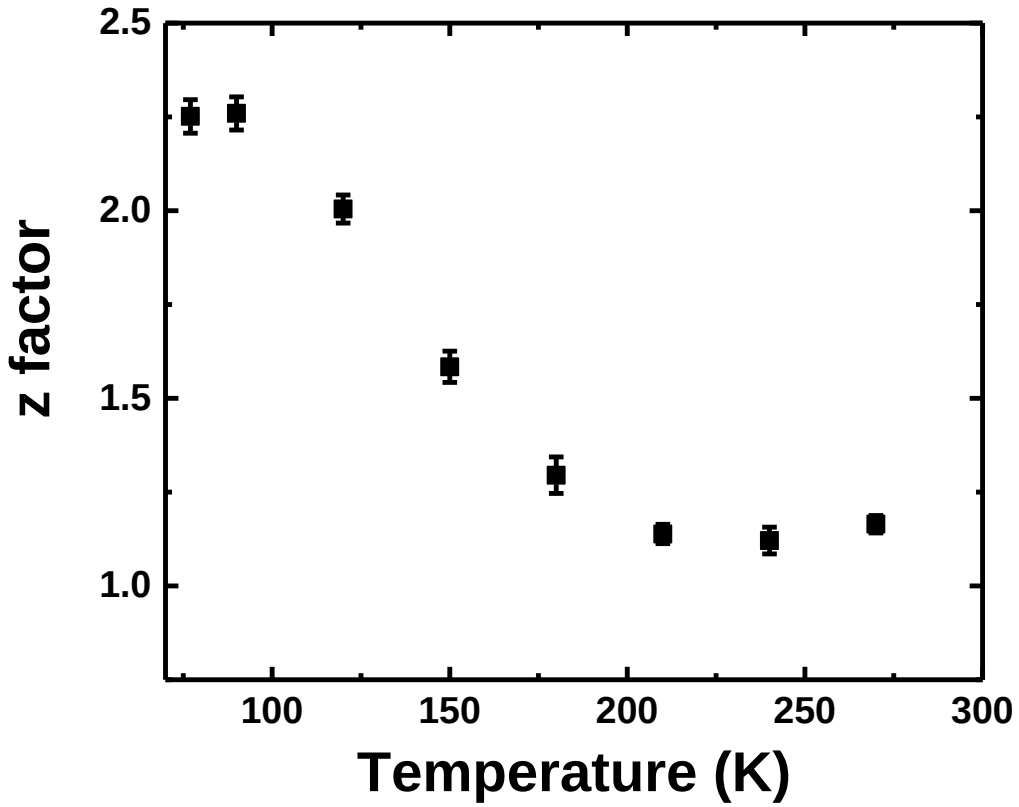




- Blue shift at 77 K as the current injection increases;
- Fast quenching of the EL above 120 K.

# Effective Dominant Recombination Process




$$I = eV(An + Bn^2 + Cn^3) + I_{leak}$$

$$I \propto n^z \propto L^{1/2^z}$$

Phillips, Alistair F., et al. *IEEE Journal of selected topics in quantum electronics* 5.3 (1999): 401-412.

- Radiative recombination evident below 120 K;
- Non-radiative recombination (SRH) dominates above 150 K.

# Conclusions

- An InAs/$GaAs_{0.86}Sb_{0.14}$ QDSC and a GaAsSb control cell were investigated using complementary PL and EL measurements.
- Defect states associated with the lattice mismatch between GaAsSb and GaAs are found to limit the performance of the solar cell.
- A rapid quenching of the PL and EL intensity, along with the shift (above 120 K) of the dominant recombination mechanisms from radiative to non-radiate processes support this hypothesis,

# Acknowledgment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