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Study of Tb³⁺-Yb³⁺ doped Silicon Nitride frequency conversion layers for Solar Cell Applications

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Motivations

- Improving solar cells efficiency by adding a Down-Conversion layer on top of it
 → Tb³⁺-Yb³⁺ doped Silicon Nitride
- System compatible with the Si solar cell fabrication
 → SiN_x as matrix

Growth

- Confocal reactive magnetron co-sputtering

Fixed parameters:

- Deposition temperature, T_{dp} = 200°C
- Plasma pressure, P_{tot} = 3mTorr
- Gas inlet, Argon and Nitrogen (8 and 2 sccm)

Tuned parameters:

- Radio-frequency power density, RFP_{target} (W/cm²)

- Annealing : RTA at 850°C for 10 min

SiN_x-Tb³⁺ system

Significant Tb emission at a non resonant excitation wavelength

→ Energy transfer from the matrix to Tb³⁺

Terbium photoluminescence

Yb³⁺ addition :Optimisation of the layer chemistry in order to obtain the maximum PL intensity

Ytterbium photoluminescence

Sizeable PL_{Yb} peak only in the presence of Tb³⁺

→ Energy transfer from Tb³⁺ to Yb³⁺ ?

PL Intensity study for various power density

The higher intensity achieved for :
 RFP_{Tb} = 4 RFP_{Yb}

Transfer efficiency

Variation of Tb³⁺ and Yb³⁺ PL intensities

- PL_{Tb} decreases substantially when Yb is added
- Adding too many Yb induces PL_{Yb} quenching

Terbium decay time

- Tb decay time :
 - τ_{Tb} (SiN_x-Tb³⁺) = 350 μs
 - τ_{Tb} (SiN_x-Tb³⁺-Yb³⁺) < 0.1 μs

→ Since there is a Yb emission, the extinction of PL_{Tb} is not due to defect quenching

→ Total transfer from Tb to Yb (confirmed by PL and PLE spectra)

→ η_{QE} = 2 * (τ_{Tb} (SiN_x-Tb³⁺) / τ_{Tb} (SiN_x-Tb³⁺-Yb³⁺)) ≈ 2 - (0.1 / 350) ≈ 2

→ Internal quantum yield ≈ 200%

Conclusion

- Evidence of the efficiency of the energy transfer from the matrix to Tb and from Tb to Yb
- Maximum internal quantum yield of 200%
- Process totally compatible with the industrial solar cells