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# Study of Tb<sup>3+</sup>-Yb<sup>3+</sup> 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  
 → Tb<sup>3+</sup>-Yb<sup>3+</sup> doped Silicon Nitride
- System compatible with the Si solar cell fabrication  
 → SiN<sub>x</sub> as matrix

### Growth

- Confocal reactive magnetron co-sputtering

**Fixed parameters:**

- Deposition temperature, T<sub>dp</sub> = 200°C
- Plasma pressure, P<sub>tot</sub> = 3mTorr
- Gas inlet, Argon and Nitrogen (8 and 2 sccm)

**Tuned parameters:**

- Radio-frequency power density, RFP<sub>target</sub> (W/cm<sup>2</sup>)

- Annealing : RTA at 850°C for 10 min

### SiN<sub>x</sub>-Tb<sup>3+</sup> system

Significant Tb emission at a non resonant excitation wavelength

→ Energy transfer from the matrix to Tb<sup>3+</sup>

Terbium photoluminescence

### Yb<sup>3+</sup> addition :Optimisation of the layer chemistry in order to obtain the maximum PL intensity

Ytterbium photoluminescence

Sizeable PL<sub>Yb</sub> peak only in the presence of Tb<sup>3+</sup>

→ Energy transfer from Tb<sup>3+</sup> to Yb<sup>3+</sup> ?

PL Intensity study for various power density

The higher intensity achieved for :  
 RFP<sub>Tb</sub> = 4 RFP<sub>Yb</sub>

### Transfer efficiency

Variation of Tb<sup>3+</sup> and Yb<sup>3+</sup> PL intensities

- PL<sub>Tb</sub> decreases substantially when Yb is added
- Adding too many Yb induces PL<sub>Yb</sub> quenching

Terbium decay time

- Tb decay time :
  - τ<sub>Tb</sub> (SiN<sub>x</sub>-Tb<sup>3+</sup>) = 350 μs
  - τ<sub>Tb</sub> (SiN<sub>x</sub>-Tb<sup>3+</sup>-Yb<sup>3+</sup>) < 0.1 μs

→ Since there is a Yb emission, the extinction of PL<sub>Tb</sub> is not due to defect quenching

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

→ η<sub>QE</sub> = 2 \* (τ<sub>Tb</sub> (SiN<sub>x</sub>-Tb<sup>3+</sup>) / τ<sub>Tb</sub> (SiN<sub>x</sub>-Tb<sup>3+</sup>-Yb<sup>3+</sup>)) ≈ 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