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Integration of rare earth ions doped Si based down converter layers in an industrial Si solar cell

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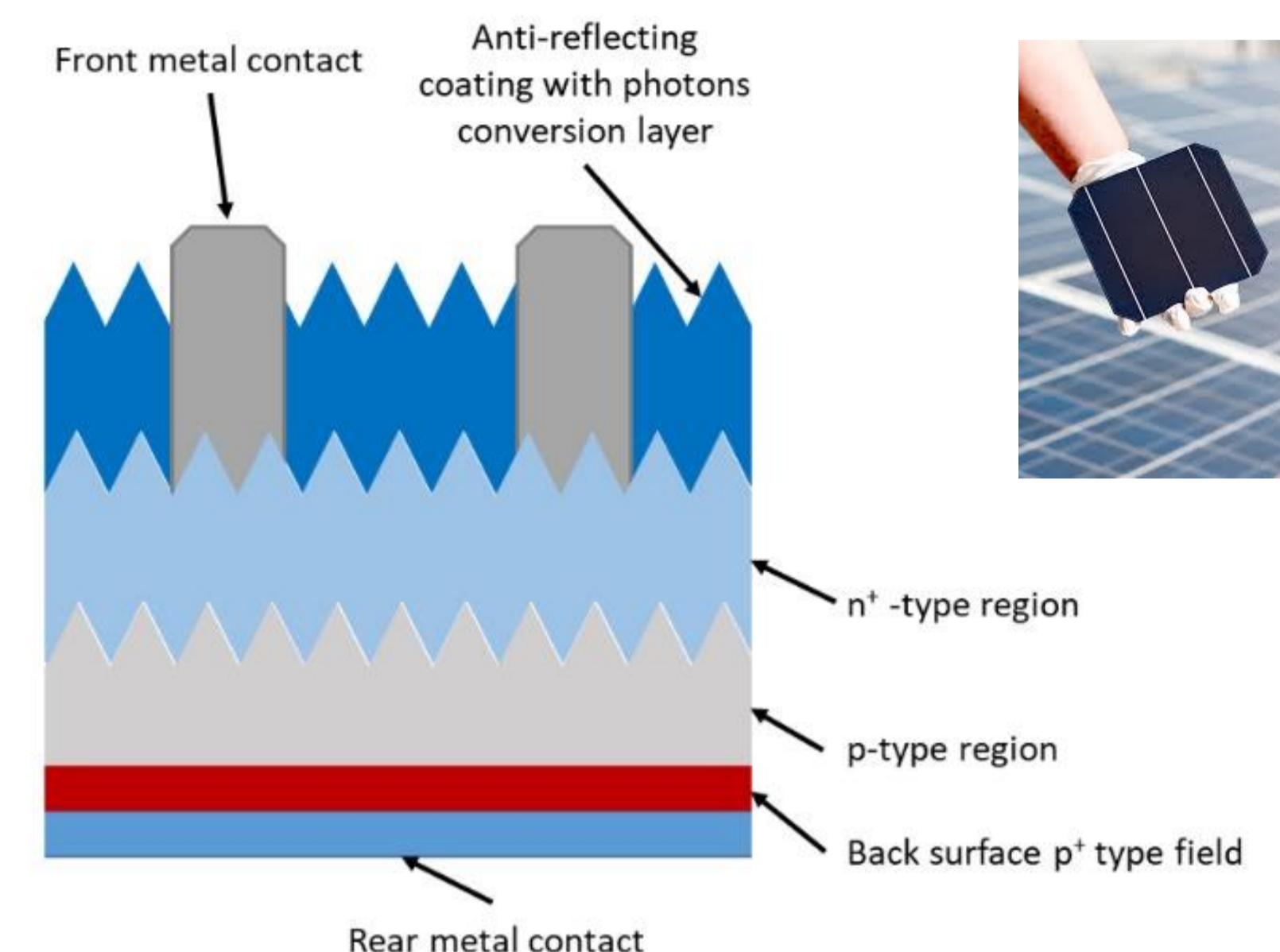
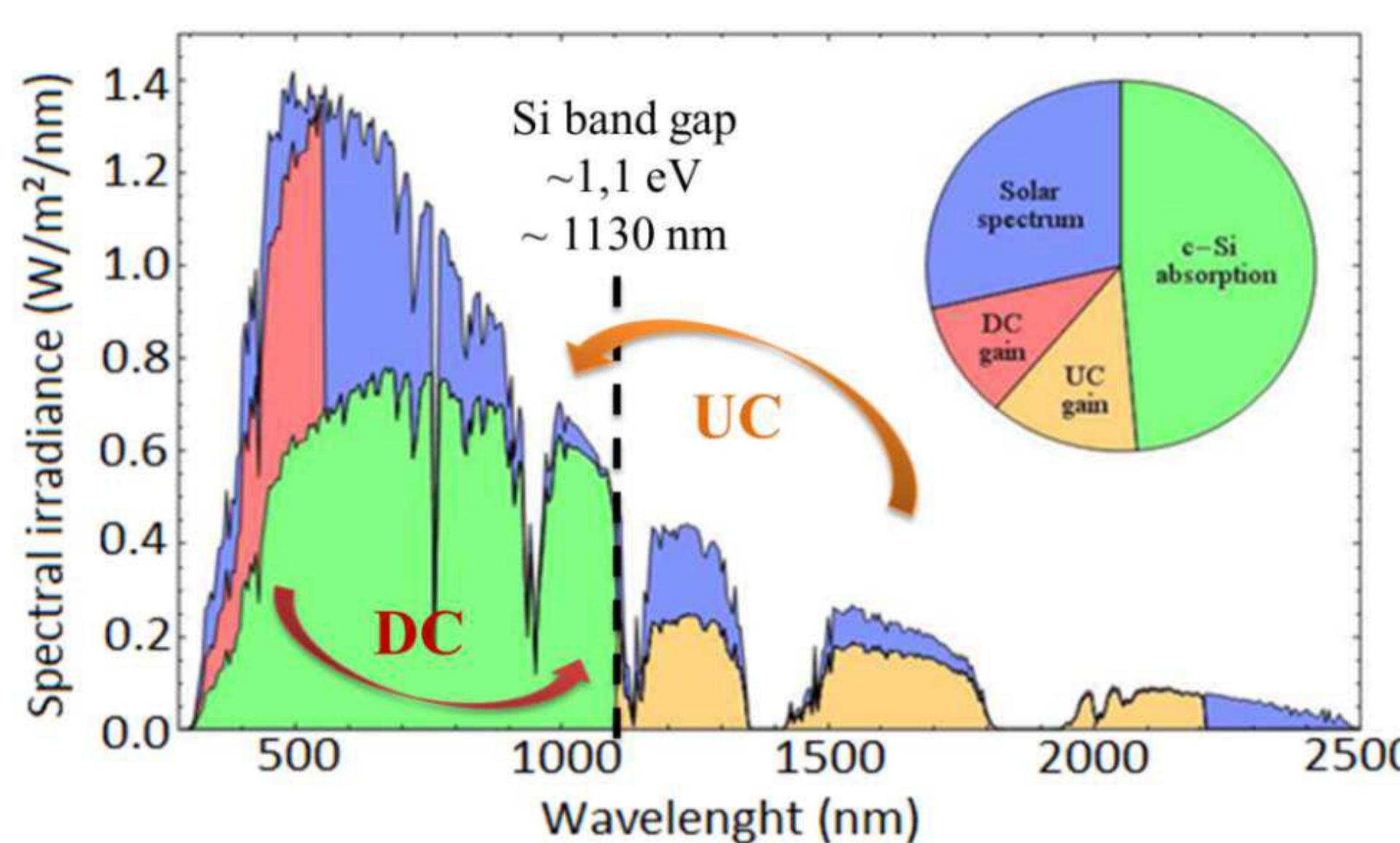
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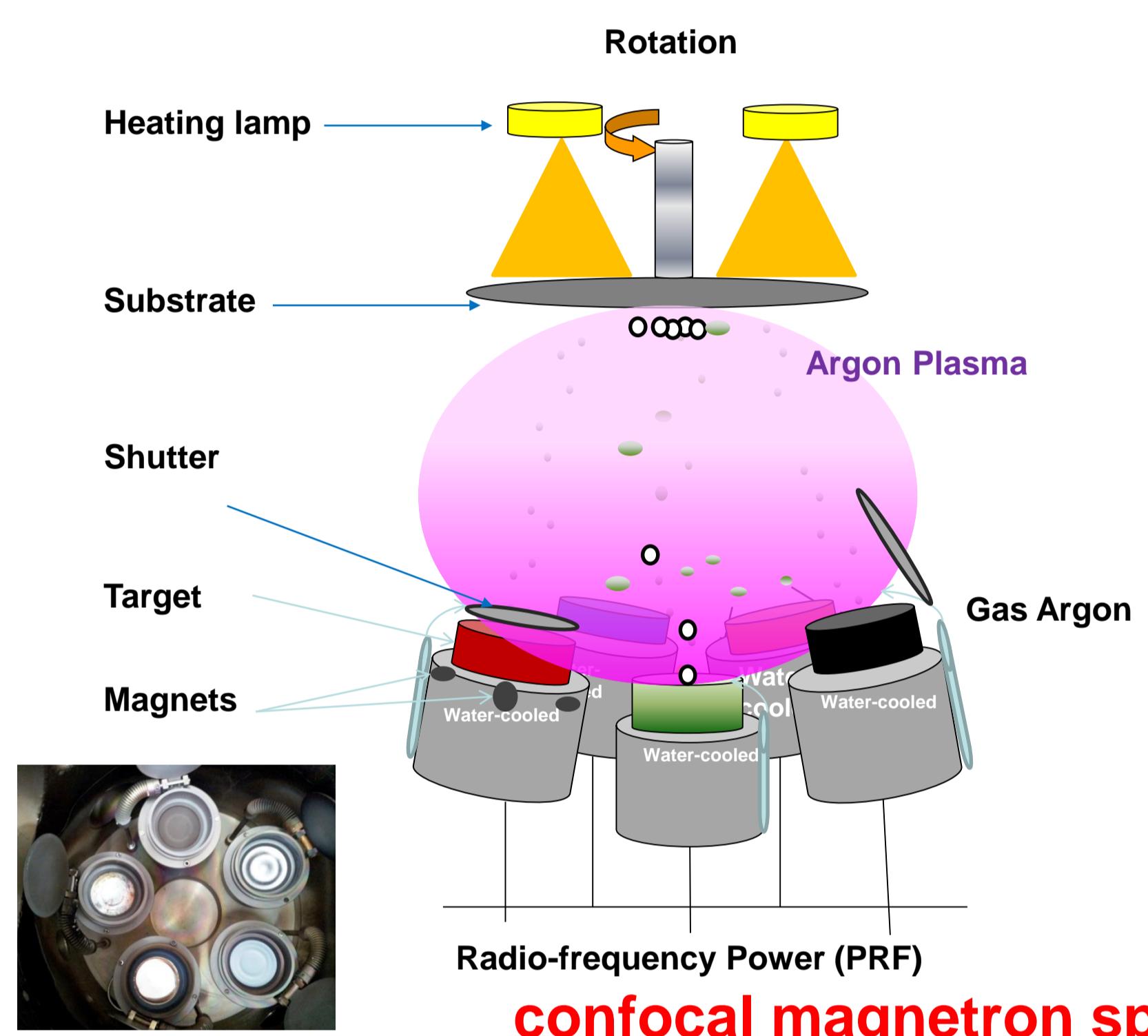
Introduction

Goal : Improve the efficiency of Si solar cells by down converter layer

- Decrease the thermalization losses due to the spectral mismatch between the solar irradiance and the Si absorption
- Use the optical properties of rare earth ions embedded in a Si-based matrix to do Down-conversion (DC)



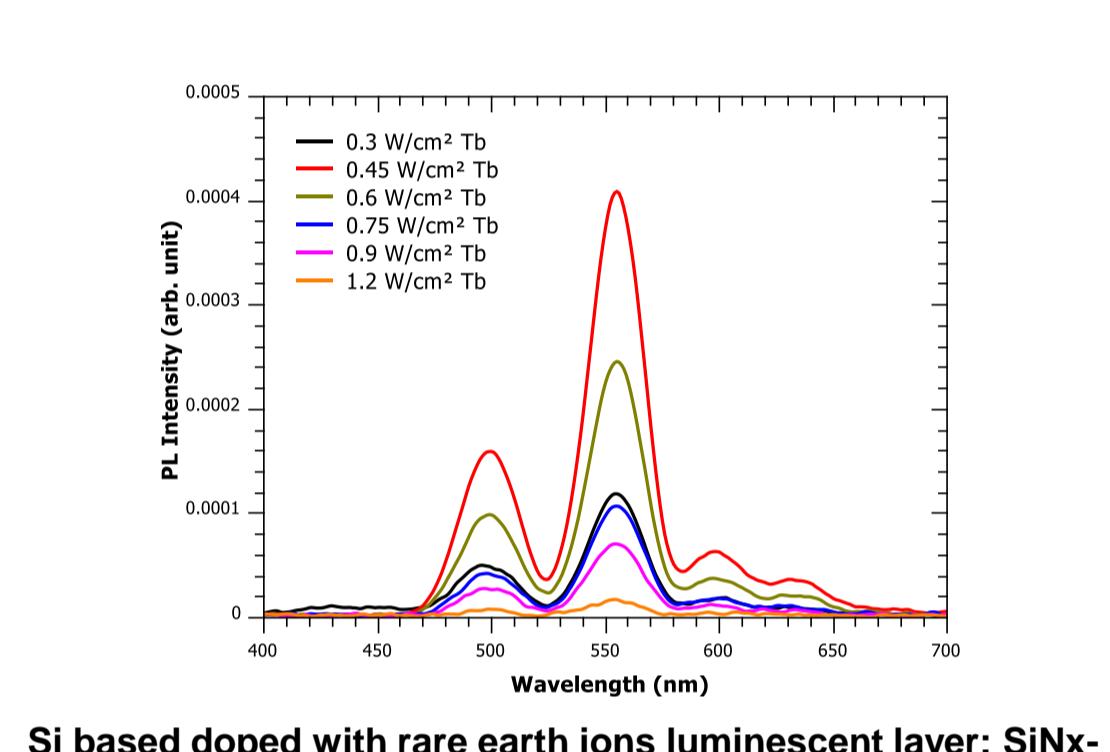
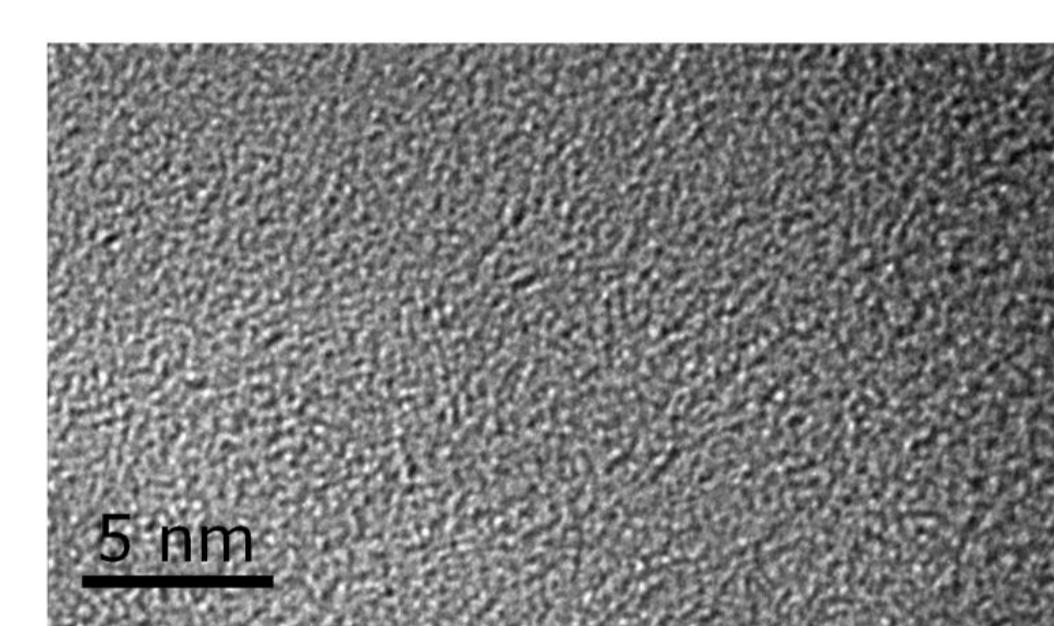
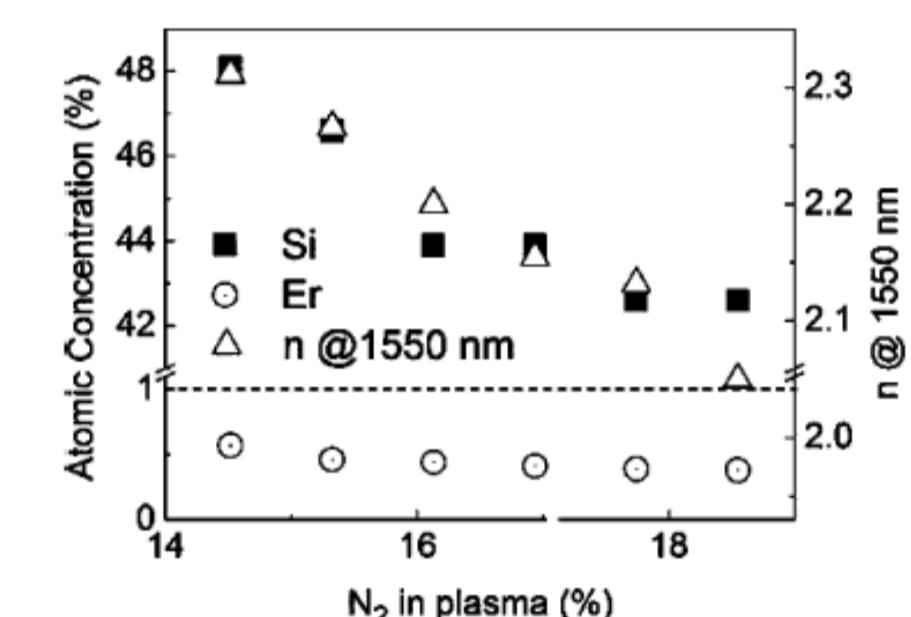
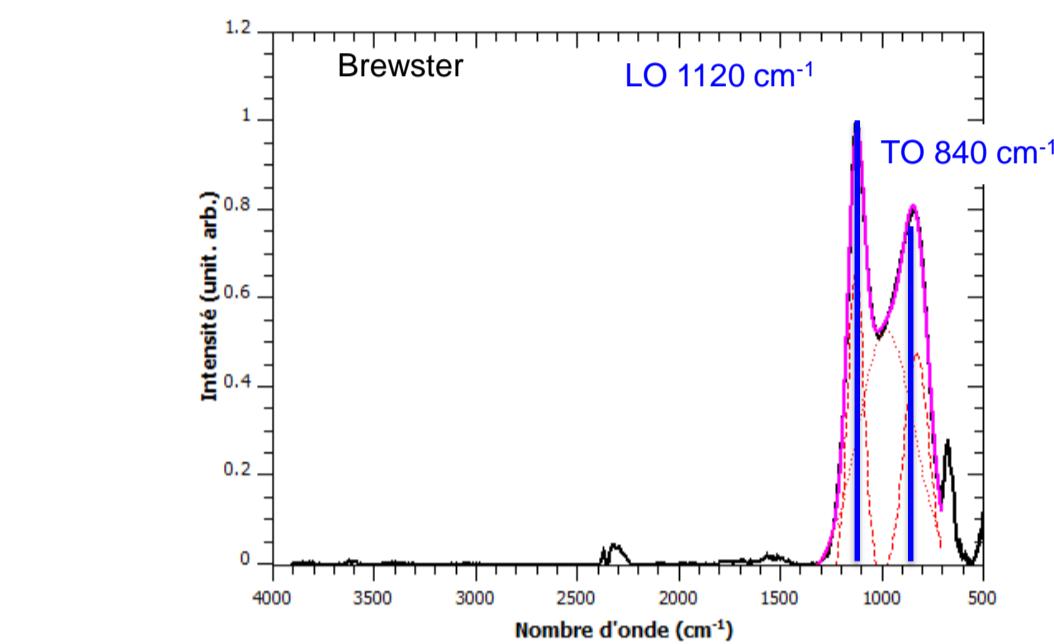
Sample fabrication



Fabrication parameters:

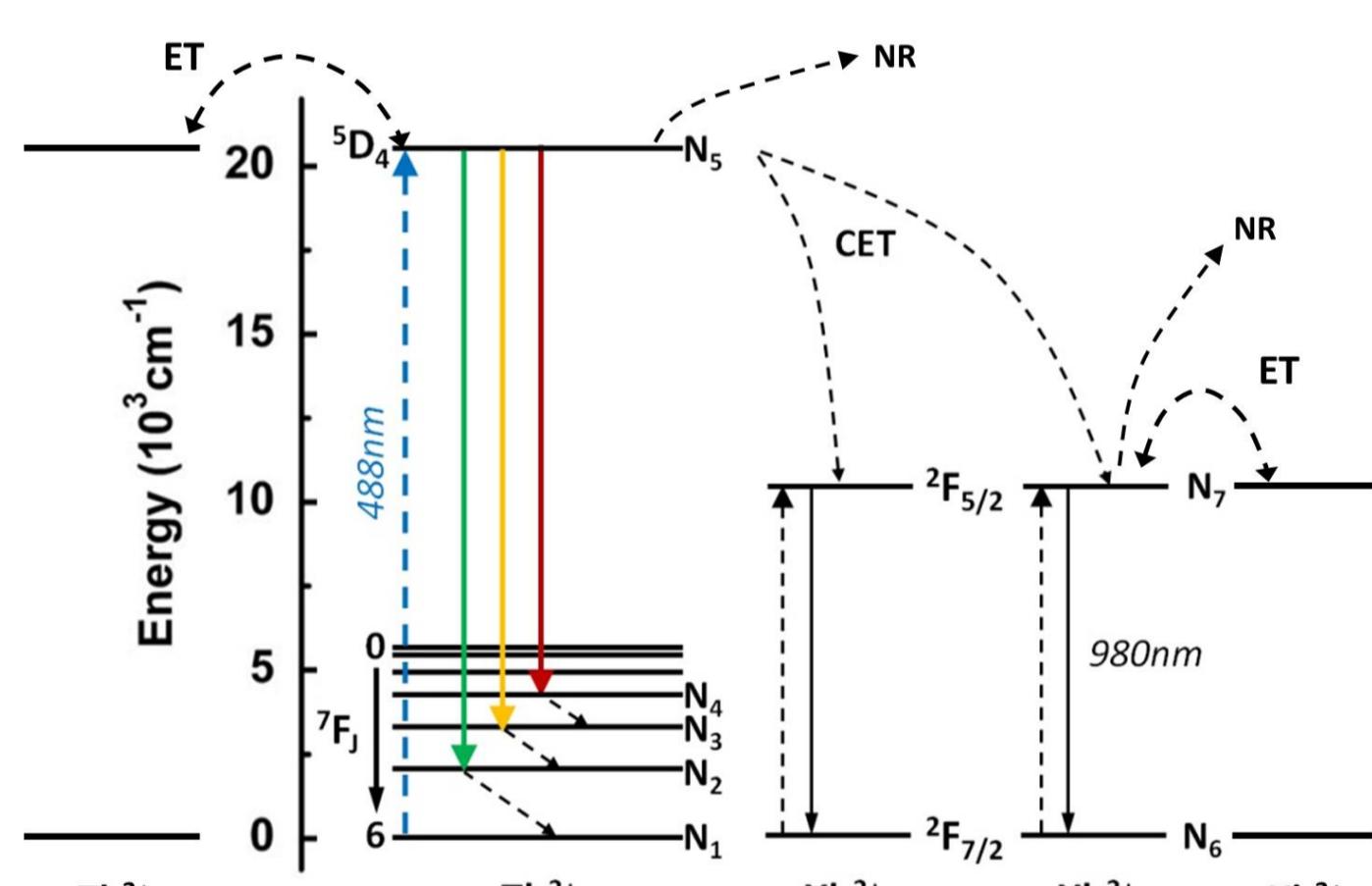
Depositions parameters:

- Deposition Temperature, T_{dp} (°C)
- Plasma Pressure, P_{tot} (sccm)
- Gaz : Argon and nitrogen
- Nitrogen rate, rN_2
- RF Power density on target, P_{target} (W/cm²)
- Depositing time, t_{dp} (s)
- Annealing with rapid or slow ramp of T under specific gas (N₂, Forming...)



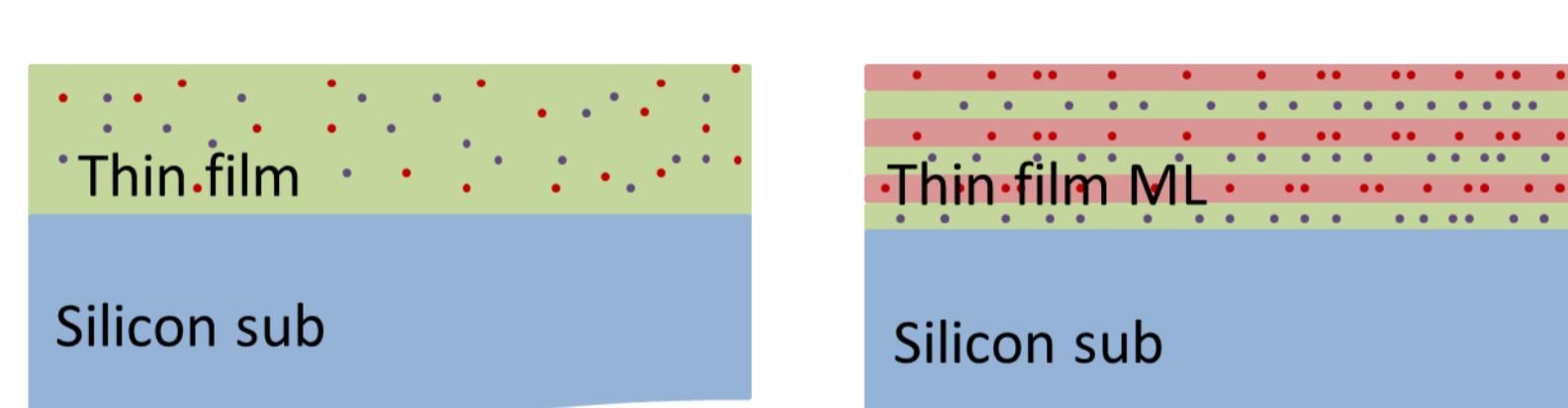
Structural and physical characterization

Monte Carlo Modeling

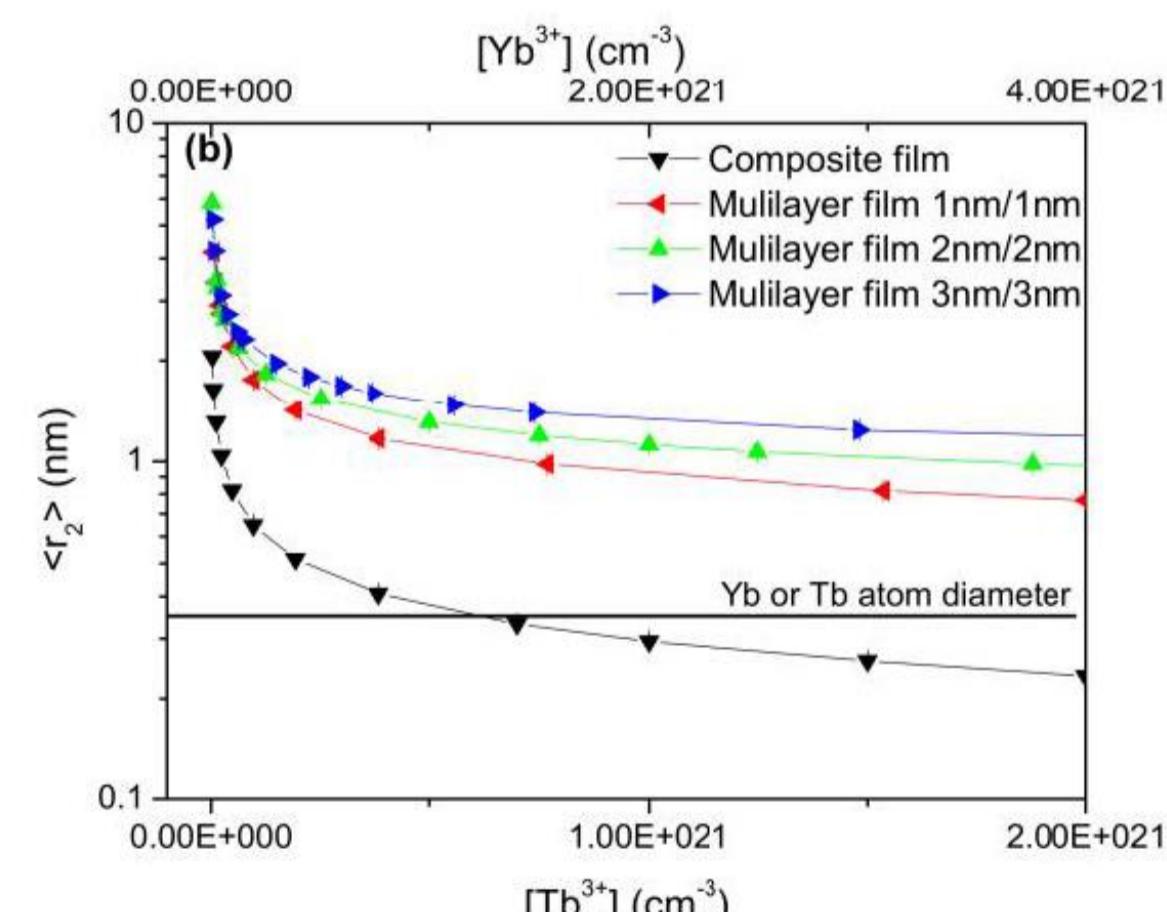
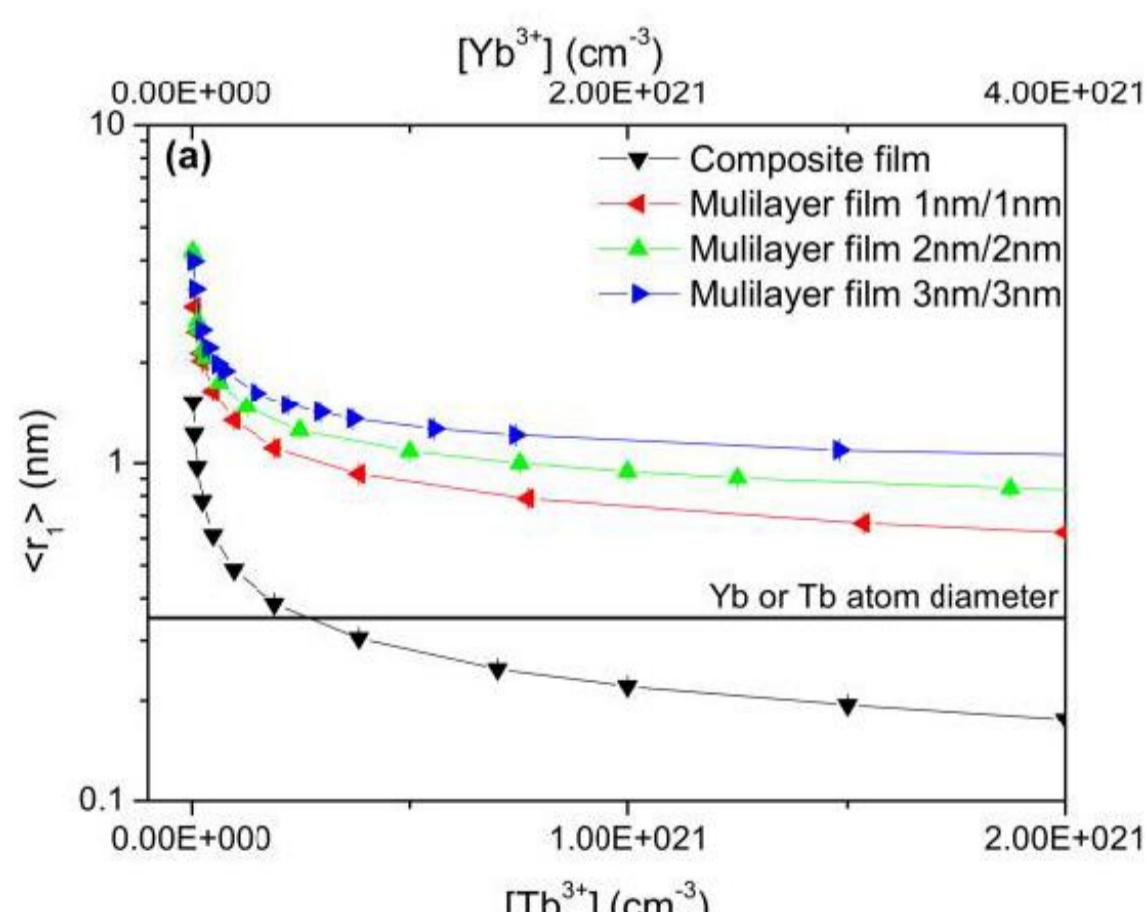


K_{CET} distance dependent and therefore function of concentration [Tb³⁺] and [Yb³⁺] and their distribution

$$K_{CET} \propto \frac{1}{r_{Tb^{3+}-Yb^{3+}}^6 \cdot r'_{Tb^{3+}-Yb^{3+}}^6}$$

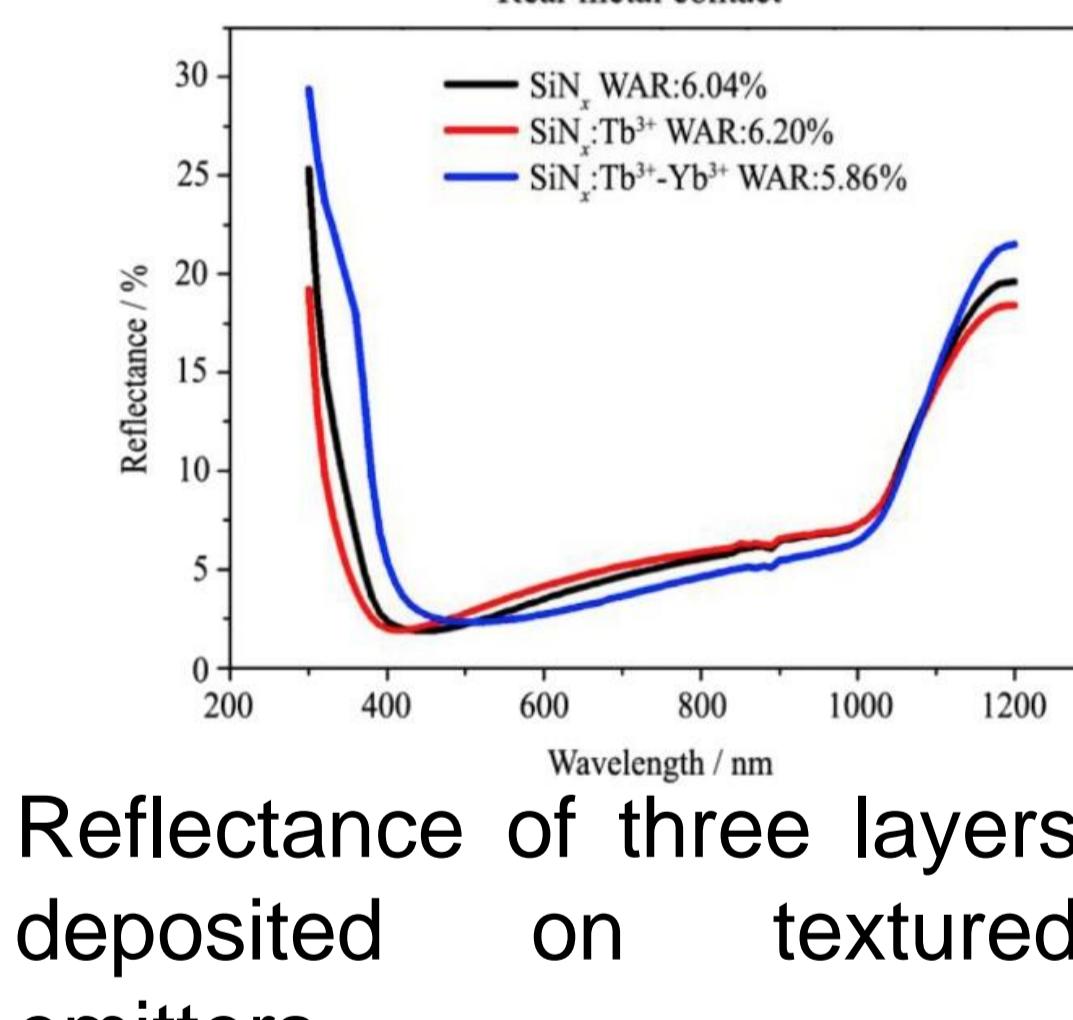
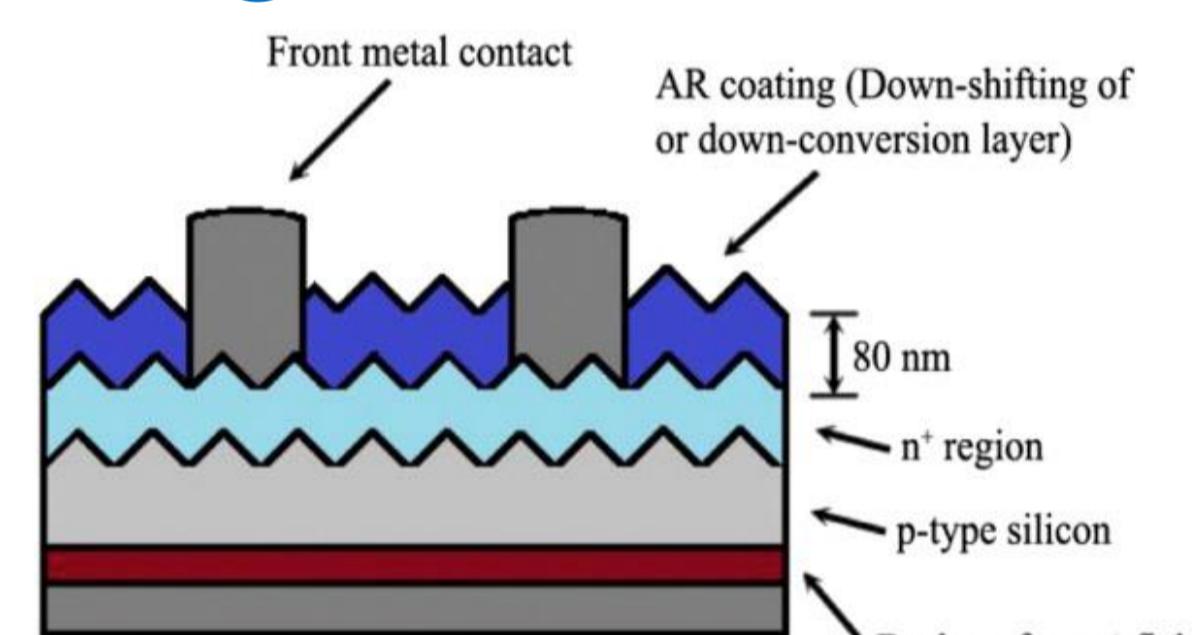


Two kinds of Tb³⁺-Yb³⁺ co-doped thin films fabricated homogenous and multilayer

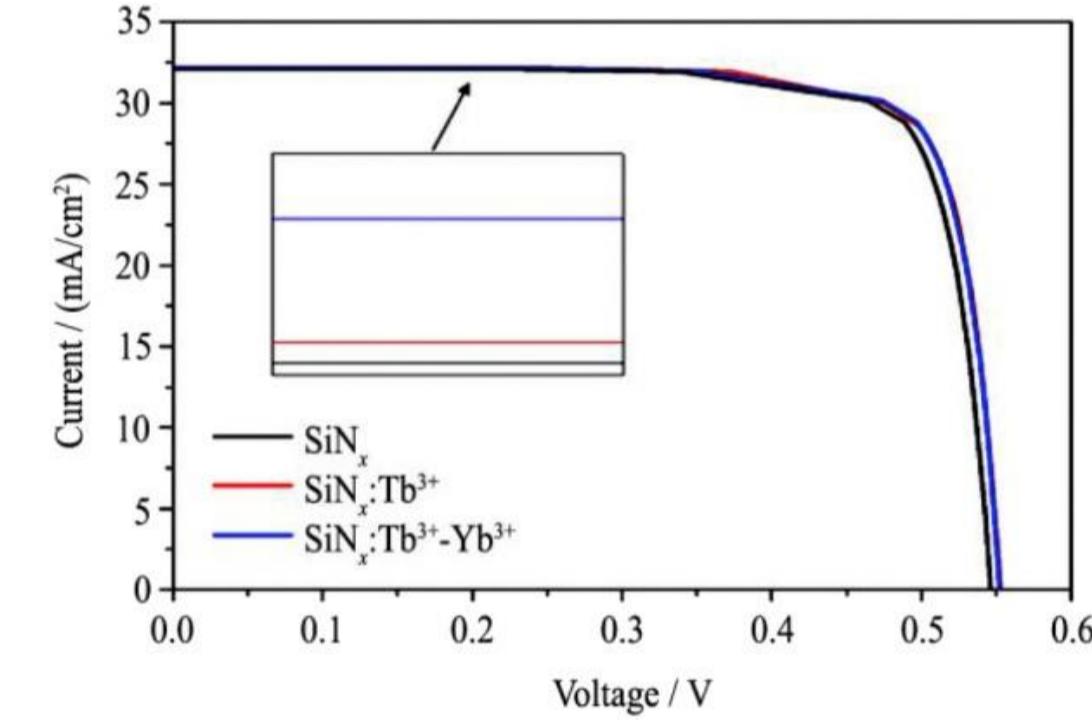
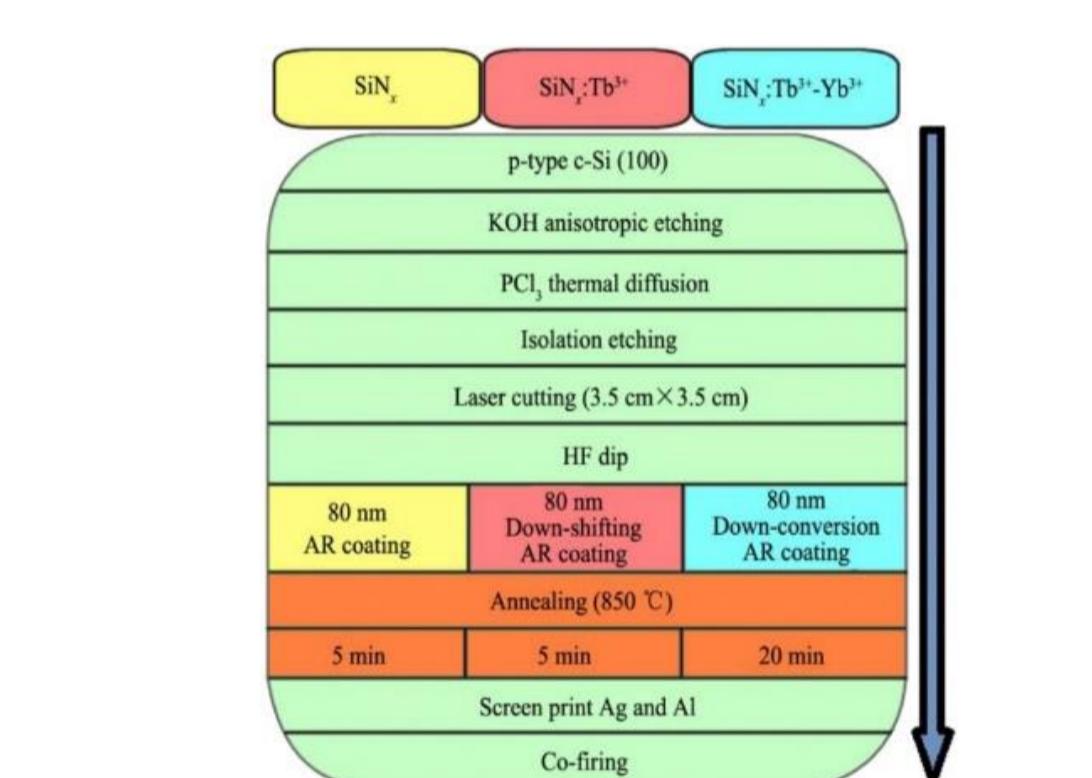


Multilayer prevent aggregation quenching and allow therefore higher doping rate

Integration in industrial Si solar cell



Reflectance of three layers deposited on textured emitters



Pseudo I-V curves for three c-Si solar cells with SiN_x, SiN_x:Tb³⁺ and SiN_x:Tb³⁺-Yb³⁺ layers, respectively.

Samples J_{sc} (mA/cm²) V_{oc} (V) Pseudo FF (%) Pseudo Efficiency (%) Efficiency to normalized transmission (%)

SiN _x	32.091	0.546	0.804	17.13	18.23
SiN _x :Tb ³⁺	32.098	0.552	0.803	17.31	18.45
SiN _x :Tb ³⁺ -Yb ³⁺	32.165	0.552	0.806	17.36	18.44

Relative increase by 1.34% in the solar cell conversion efficiency

Conclusion

- Fabrication of Tb/Yb-doped SiN_x homogenous and multilayer films
- Modeling of the DC interaction exchange for both kind of films
- Homogenous and multilayer DC layers integrated in Si solar cell
- >DC optimized films
- >Aggregation of rare earth ions is prevented in multilayer
- >Homogenous DC layer lead to relative Si solar cell efficiency increase of 1.34%



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