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

J. Cardin(1), L. Dumont(1), C. Labbé(1), P.-M. Anglade(1), C. Frilay(1), S.C. Wu(2), I.-S. Yu(2), X. Portier(1), P. Marie(1), F. Gourbilleau(1).

(1) CIMAP, Normandie Univ, ENSICAEN, UNICAEN, CEA, CNRS, 14000 Caen, France

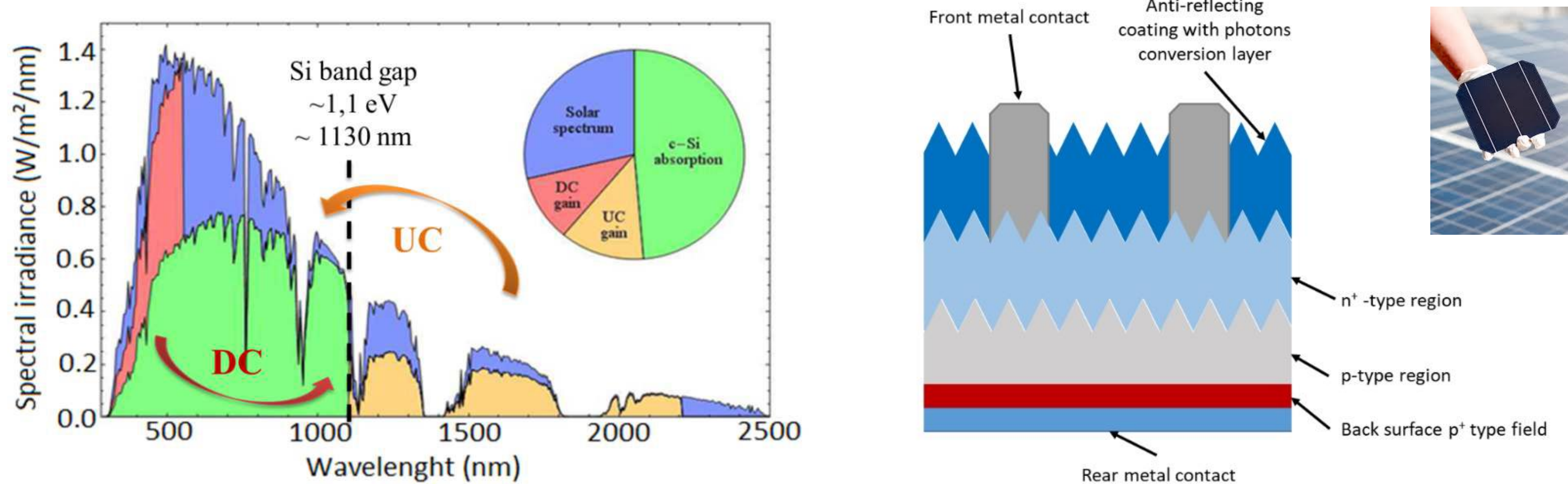
(2) Department of Materials Science and Engineering, National Dong Hwa University, Hualien, Taiwan

Email : julien.cardin@ensicaen.fr

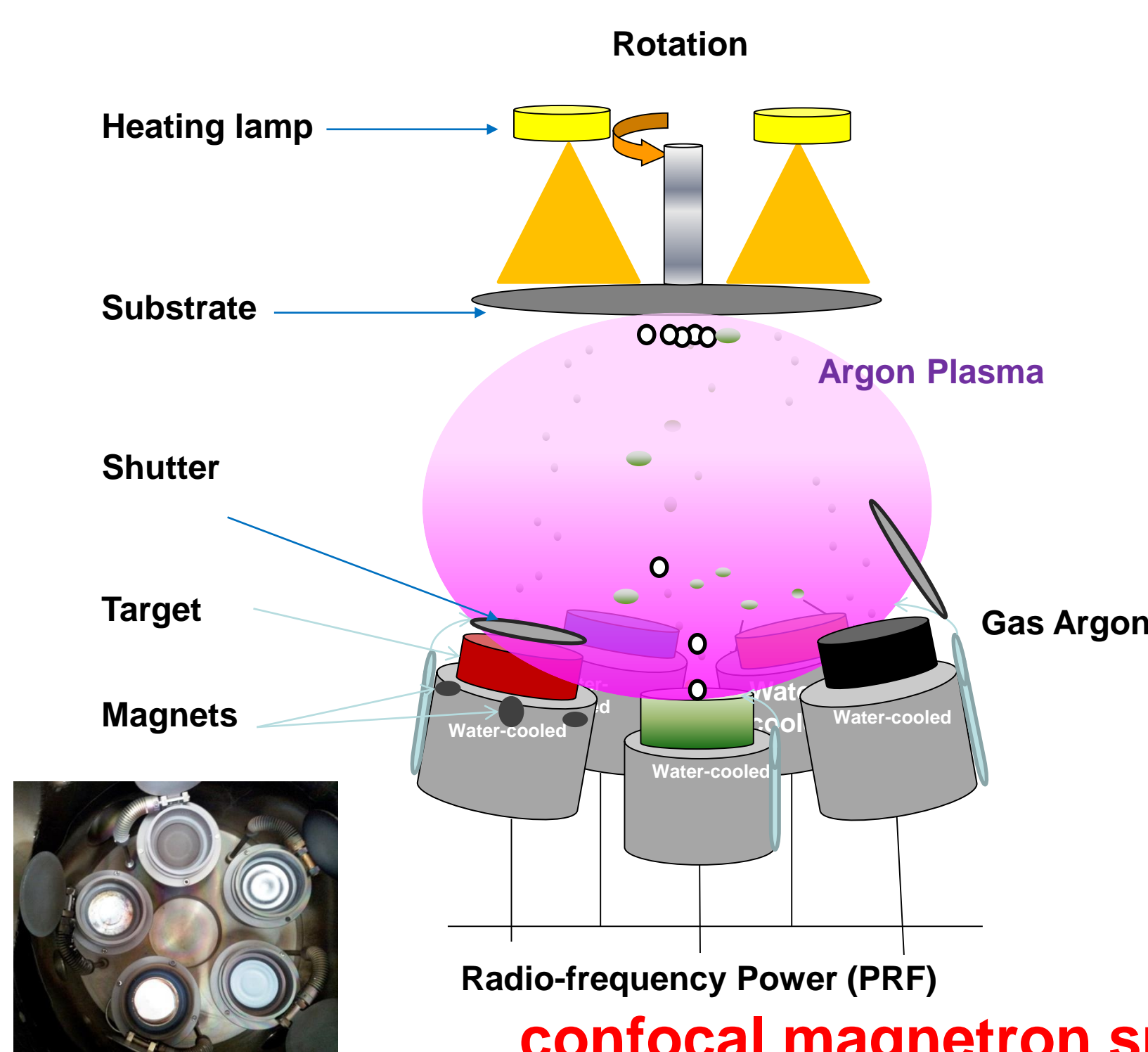
Introduction

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)**



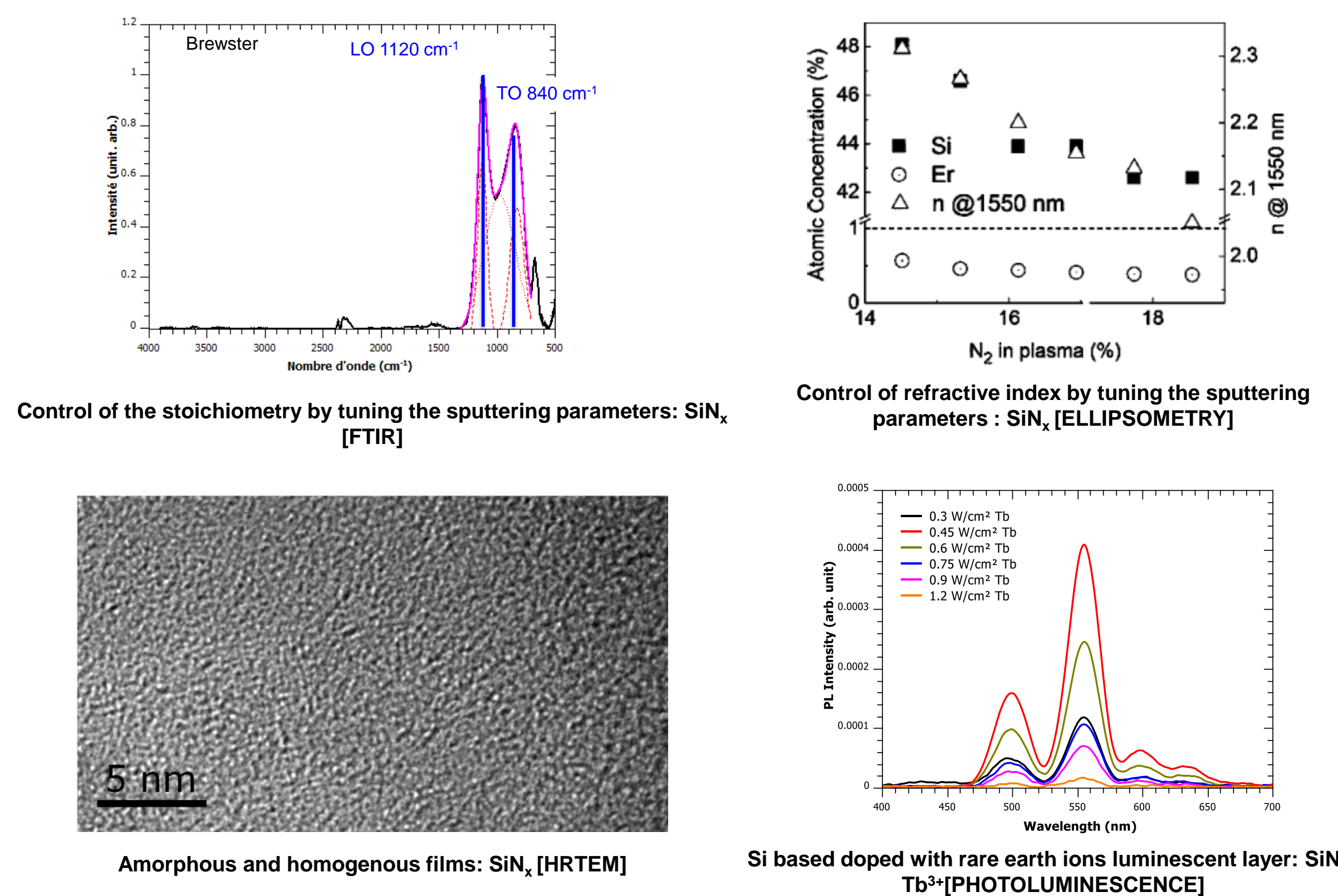
Sample fabrication



confocal magnetron sputtering

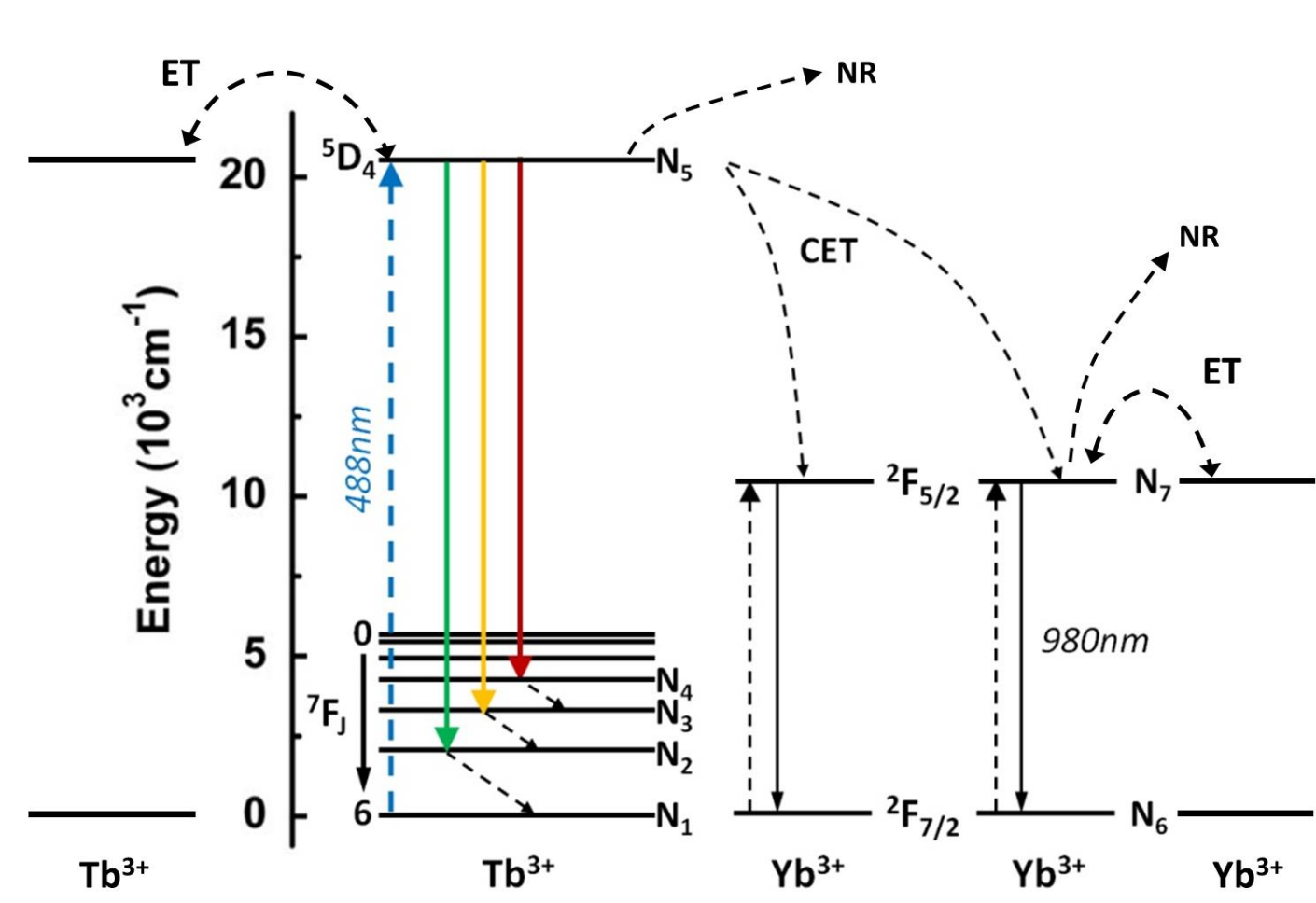
Fabrication parameters:

- Depositions parameters:
- Deposition Temperature, T_{dp} (°C)
 - Plasma Pressure, P_{tot} (sccm)
 - Gas : Argon and nitrogen
 - Nitrogen rate, r_{N_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

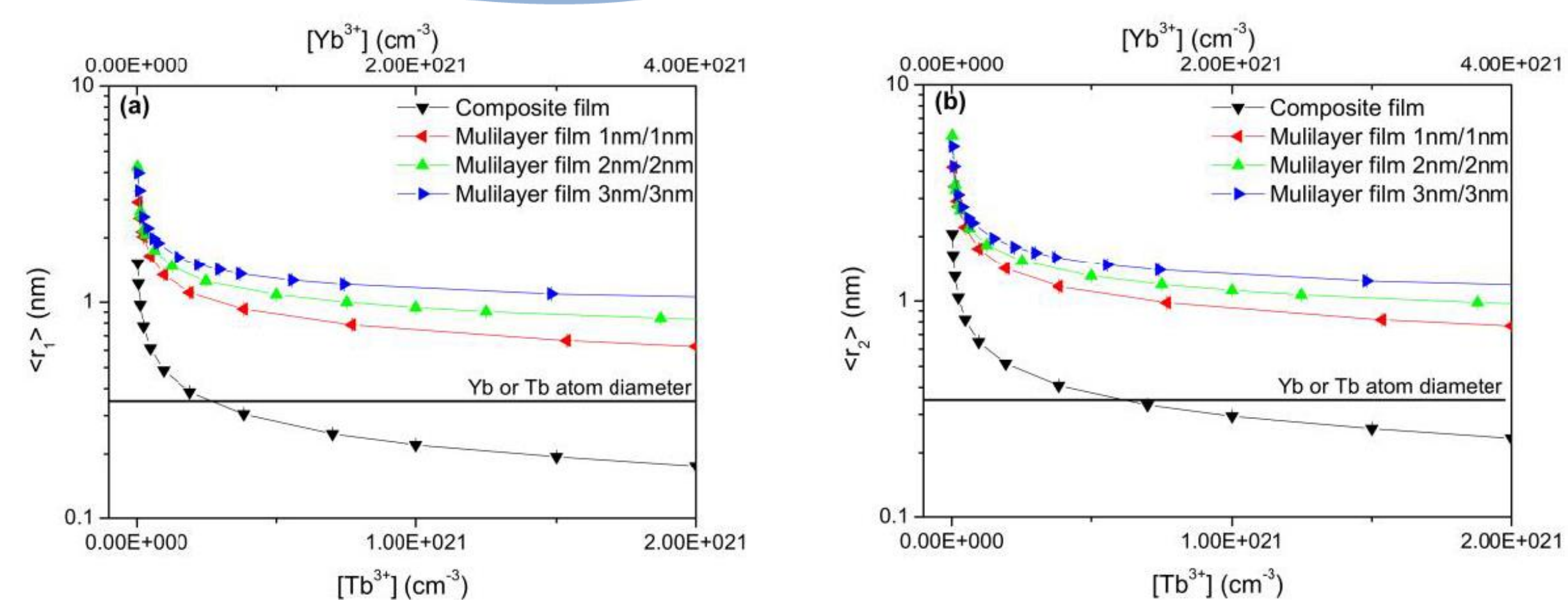
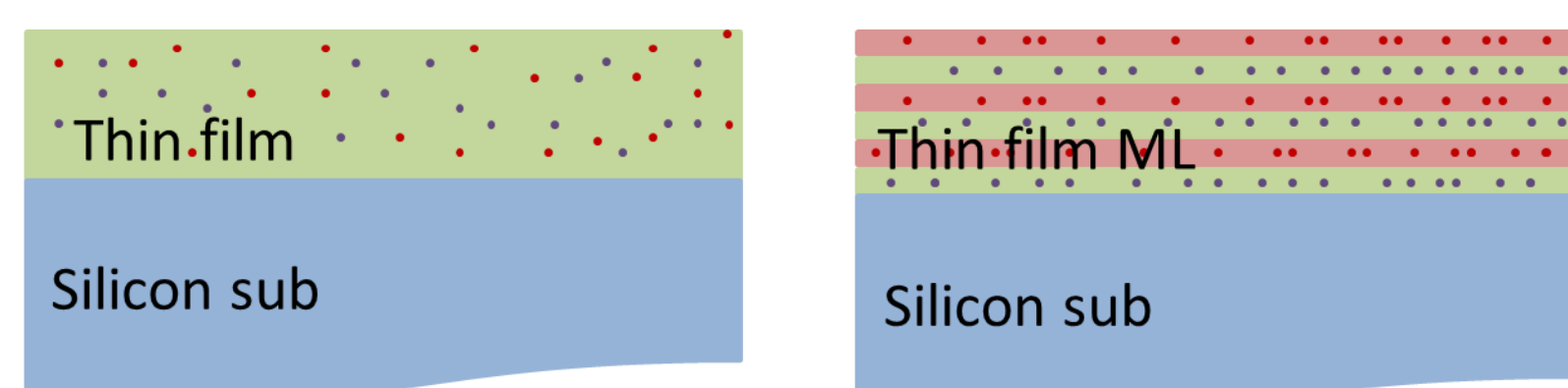
Monte Carlo Modeling



K_{CET} distance dependent and therefore function of concentration $[Tb^{3+}]$ and $[Yb^{3+}]$ and their distribution

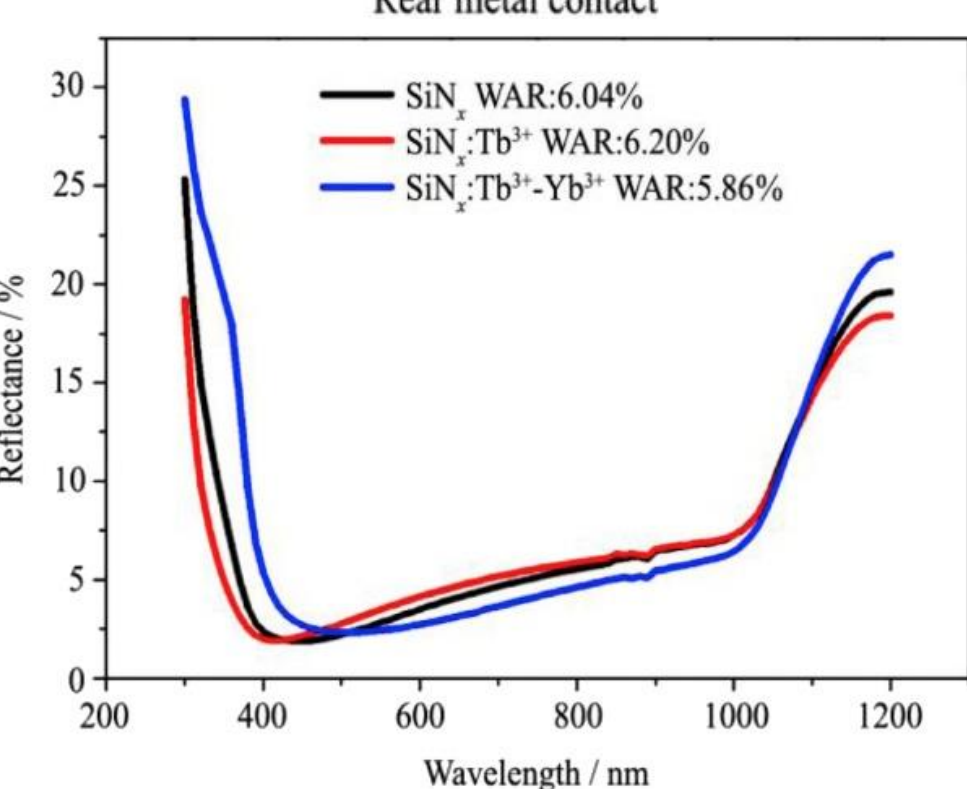
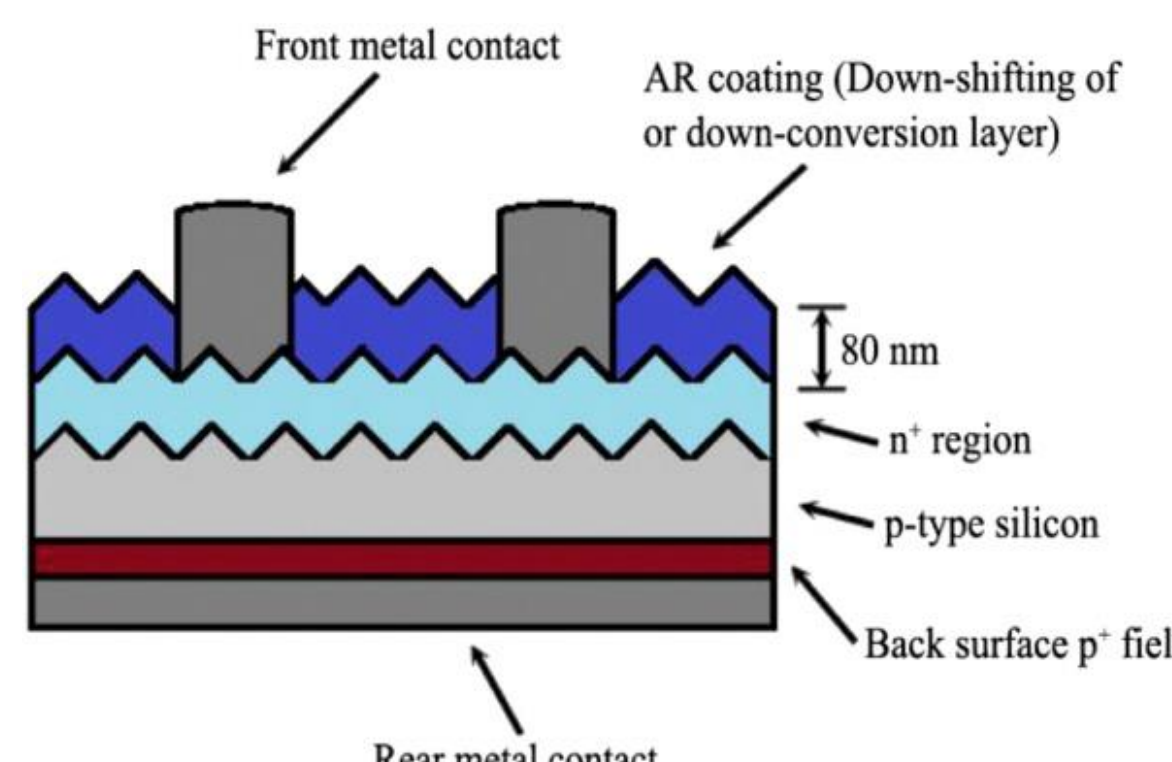
$$K_{CET} \propto \frac{1}{r_{Tb^{3+}}^6 + r_{Yb^{3+}}^6}$$

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

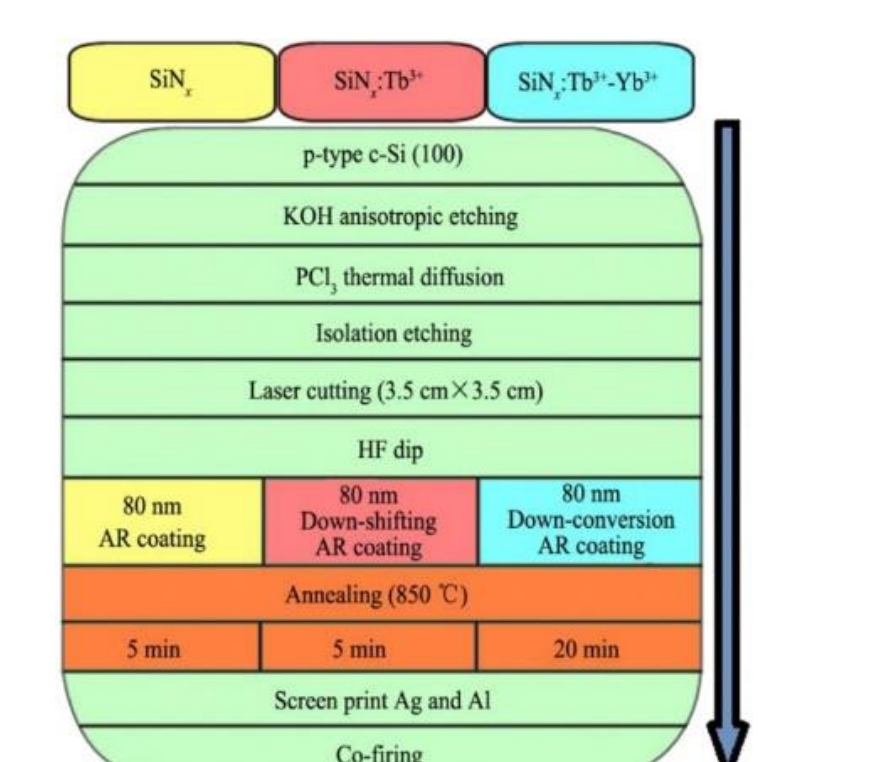


Multilayer prevent aggregation quenching and allow therefore higher doping rate

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 SiNx, SiNx:Tb³⁺ and SiNx:Tb³⁺-Yb³⁺ layers, respectively.

Samples	J_{sc} (mA/cm ²)	V_{oc} (V)	Pseudo FF (%)	Pseudo Efficiency (%)	Efficiency to normalized transmission (%)
SiNx	32.091	0.546	0.804	17.13	18.23
SiNx:Tb ³⁺	32.098	0.552	0.803	17.31	18.45
SiNx: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 SiNx homogenous and multilayer films ->DC optimized films
- Modeling of the DC interaction exchange for both kind of films -> Aggregation of rare earth ions is prevented in multilayer
- Homogenous and multilayer DC layers integrated in Si solar cell -> Homogenous DC layer lead to relative Si solar cell efficiency increase of 1.34%