

CO₂ Reduction by bio-inspired up-converting photonic structures



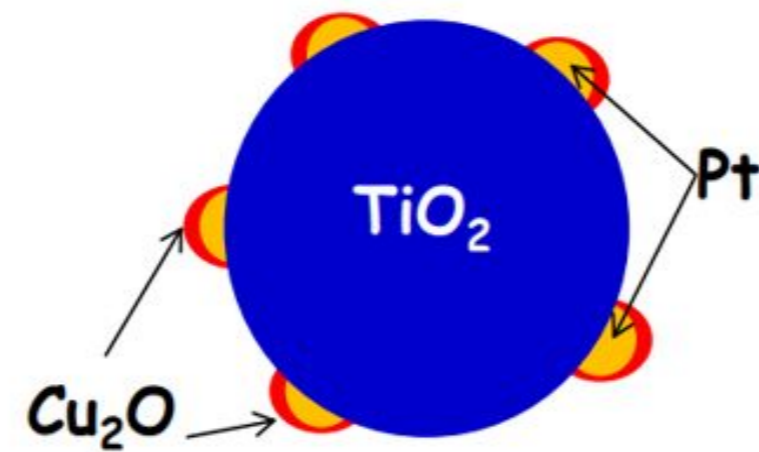
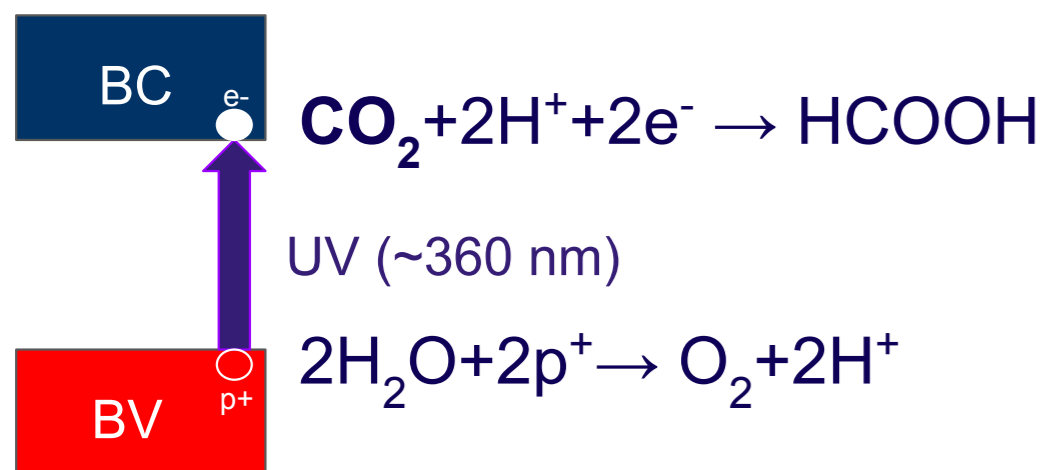
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Context and objectives: In light of the climate crisis and energetic transition, our project focuses on CO₂ valorisation via photocatalysis coupled with bio-inspired up-conversion and photonic crystals for better efficiency. The work will be carried on the synthesis of an up-converting layer, that is going to be coupled to a photonic crystal structure in possibly different ways. These structures will serve as a backbone for the photocatalysis material and efficient CO₂ reduction reaction.

Photocatalysis

CO₂ reduction reaction can be obtained by light absorption in semiconductor:



→ But low efficiency due to charge carriers recombination¹

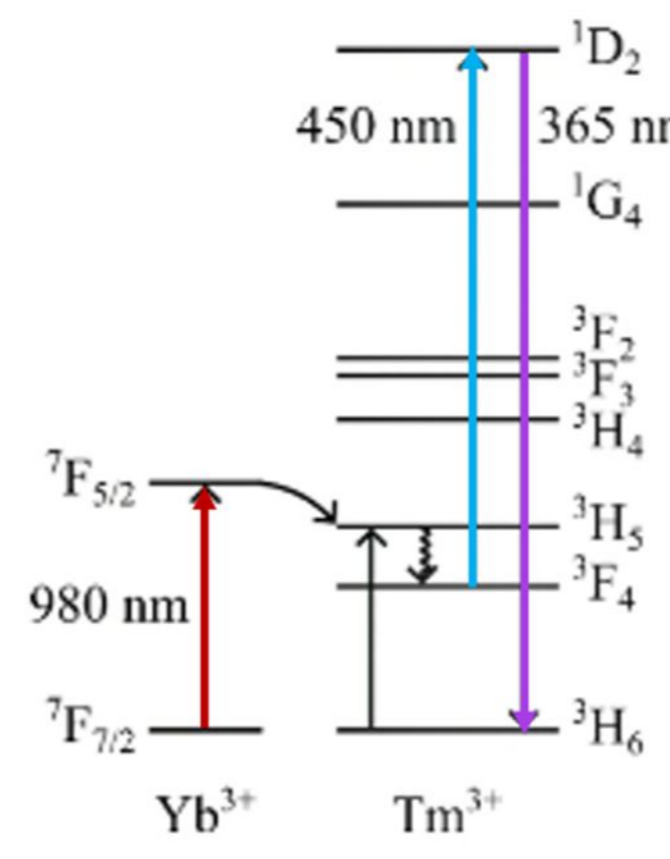
Up-conversion

Conversion of low energy light to higher energy light: NIR/VIS → UV

Material: Y₂O₃:Yb/Tm

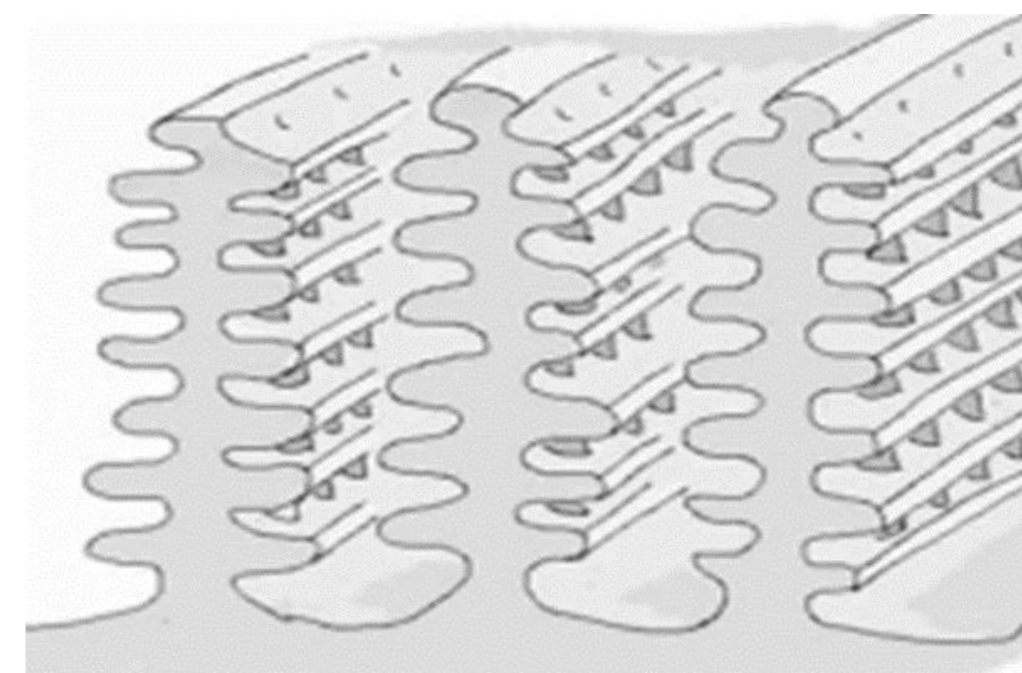
Objective: to produce UV light (360 nm) for photocatalysis

→ But low efficiency due to low absorption cross section of lanthanides²

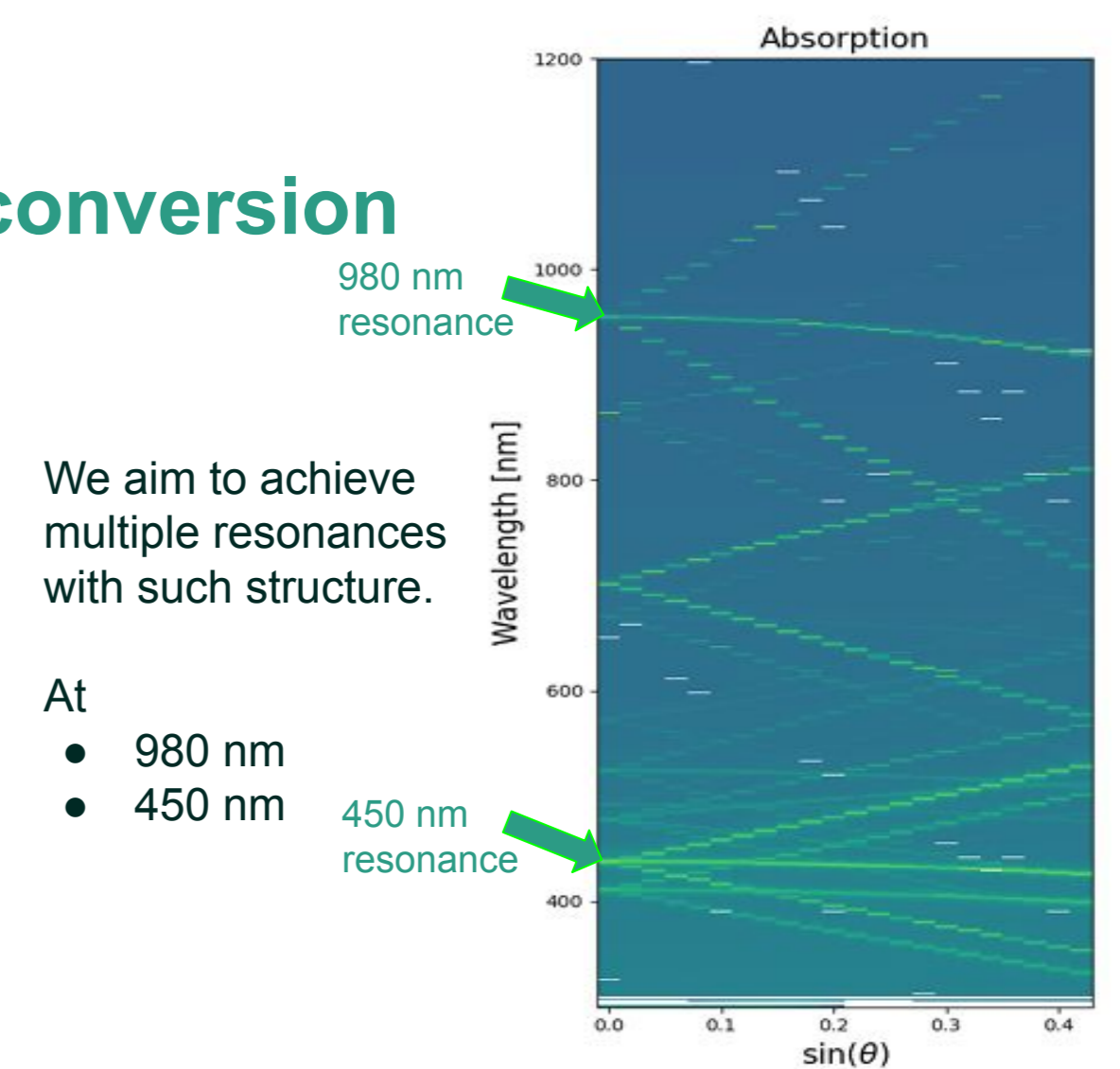


To enhance the efficiency of both photocatalysis and up-conversion photonic crystals (PC)³

- Engineering PC resonances to overlap with lanthanide resonances and increasing absorption intensity.
- Targetting multi-resonant structures with resonances at 450 and 980 nm. Bio-inspiration by morpho butterfly wings.
- Created with Laser Interference Lithography (LIL)



Schematic image of morpho butterfly wing nanostructures⁴



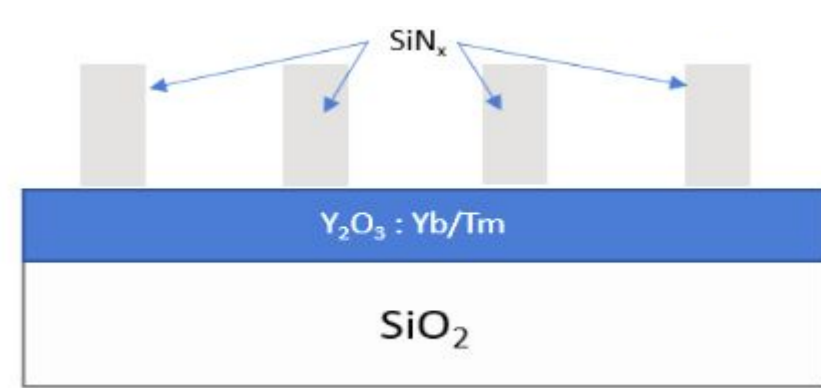
We aim to achieve multiple resonances with such structure.

At

- 980 nm
- 450 nm

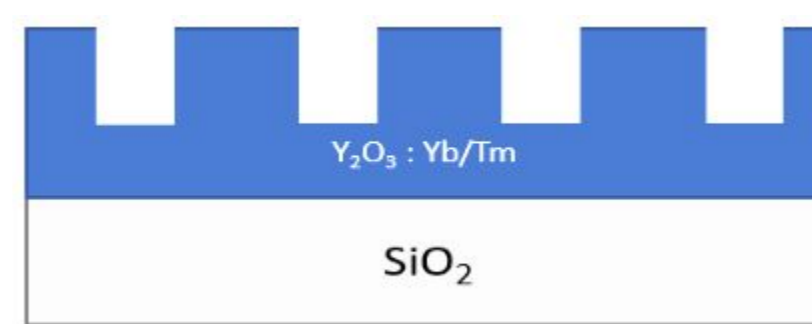
Example of a simulated band diagram of a different to our case multiresonant complex photonic structure⁵

Coupling up-conversion with Photonic Crystal



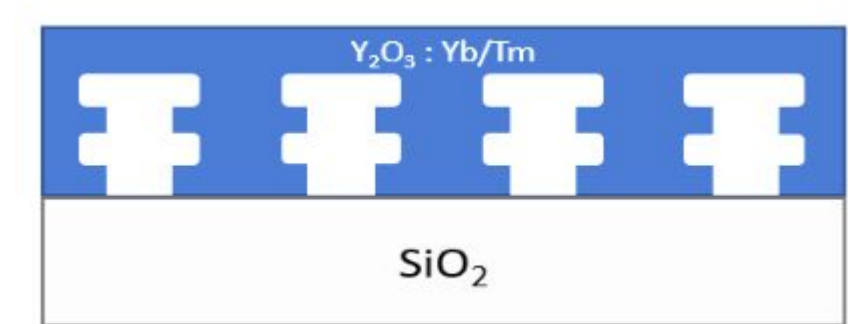
Y₂O₃ thin film within PC

Near field absorption enhancement by 'conventional' PC



Y₂O₃ thin film nanoimprint

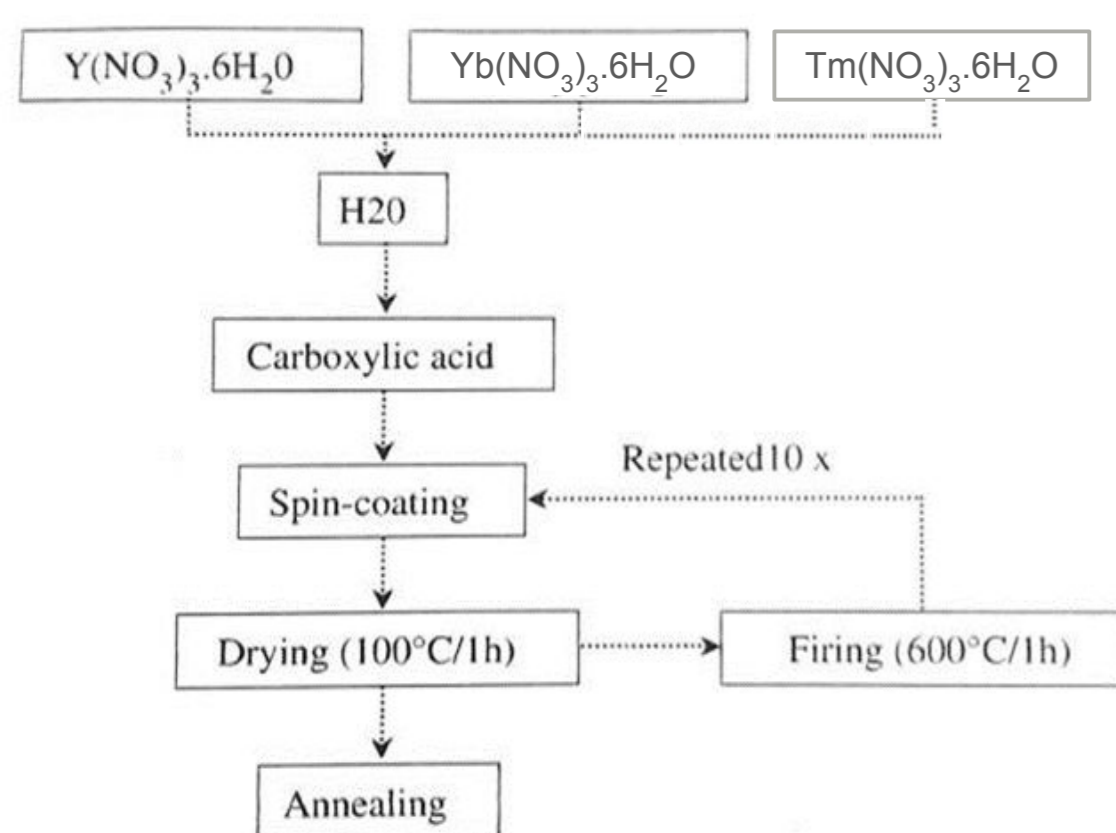
Nanostructuring the up-converter directly



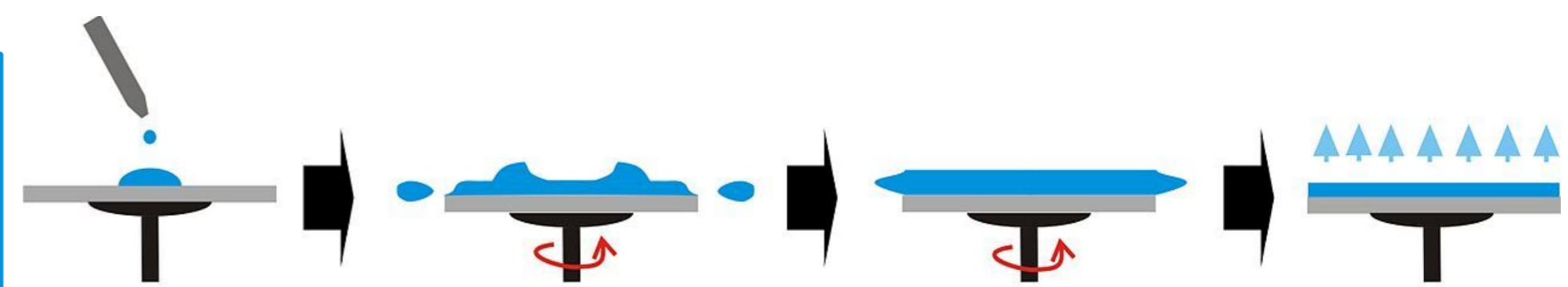
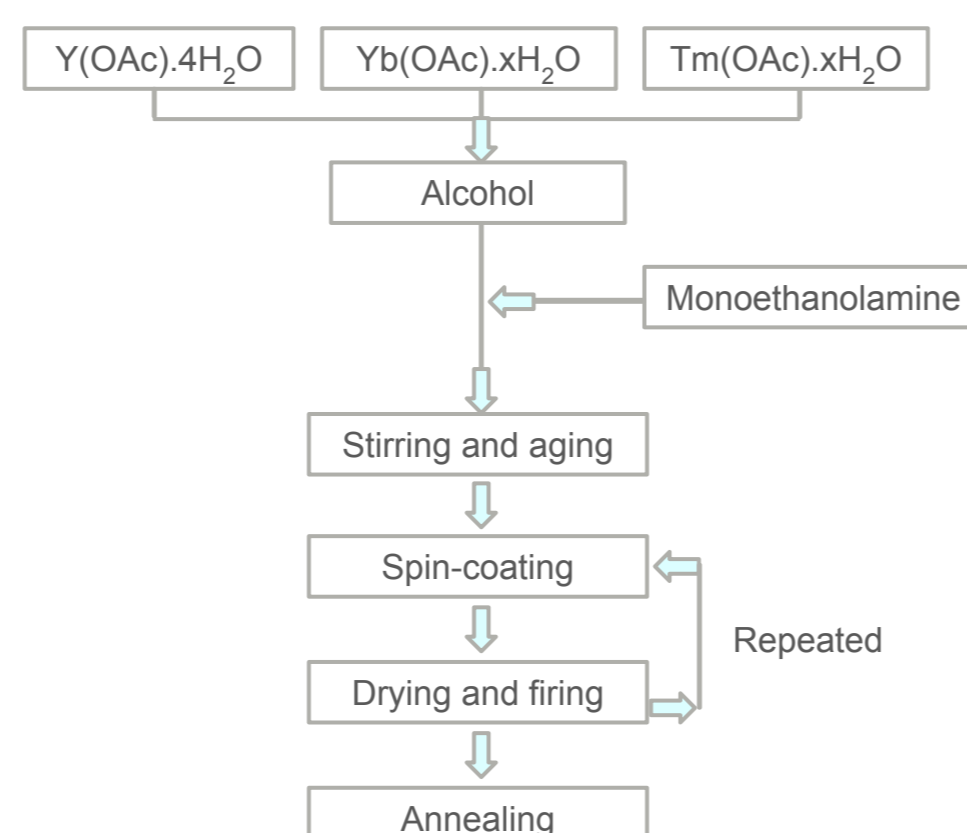
Y₂O₃ sol-gel infiltration into PC

Taking advantage of bio-inspiration of the up-converter layer

Deposition of up-converter thin films by spin-coating²: Y₂O₃:Yb/Tm



- Mixing lanthanide precursors with organic chelating agents to form lanthanide-organic complexes which form yttria oxide after calcination.
- Testing two types of sol: in aqueous solution (left), in alcoholic solution (right).



Advantages:

- Easy and low cost
- Environmentally friendly and not toxic
- Ambient T and P
- Control of thickness
- Large surfaces

Disadvantages:

- Sensible to contamination and quality of precursors
- Inhomogeneities and defects must be well controlled
- Surface treatment is essential

Conclusions

IPVF : Synthesis, characterizations of the Y₂O₃ lanthanide doped thin films (XRD, microscopy, EDX...), sol infiltration in photonic crystals.

INL : Simulations, synthesis, characterization of photonic crystals, nanoimprint tests on sols.

Work on photocatalytic material incorporation to be considered later.

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Bibliography

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