INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

LPCNO Laboratoire de Physique & Chimie des Nano-Objets

High-performance photovoltaics through the assembly of thick nanoparticle-based microstructures

Laboratory of Physics and Chemistry of Nano-Objects (LPCNO-UMR 5215 INSA-CNRS-UPS) @ Toulouse

- PhD in the field of nanotechnology
- Duration: 3 years
- Location: Toulouse (France), on the INSA campus

Keywords: Nanoparticles, quantum dots, directed assembly, microfabrication, photovoltaics

Scientific context

Faced with the climate emergency, improving the performance of photovoltaic technologies is a major challenge for the energy transition. Currently, silicon-based solar panels plateau at efficiencies of around 20%, largely due to a fundamental mismatch between the incident solar spectrum and the silicon's absorption capacity.

A promising way to bypass this limitation is to integrate **light conversion layers** capable of transforming solar photons into wavelengths better suited to silicon. These layers rely on photoluminescent nanoparticles (**quantum dots**), which are able to absorb and re-emit light in a controlled manner.

However, current approaches remain limited by:

- the need for thick layers (1–2 µm) for efficient absorption,
- challenges in structuring at the micro/nano scale,
- strong constraints related to the use of non-polar solvents, which are not compatible with conventional deposition techniques.

In this context, our team has recently developed and patented [1-2] an **innovative directed self-assembly method** based on *Convective Self-Assembly (CSA)* coupled with functionalized microstructured substrates (Fig.1a). This approach allows the formation of organized 3D architectures of nanoparticles, paving the way for a new generation of optical conversion layers (Fig. 1b).

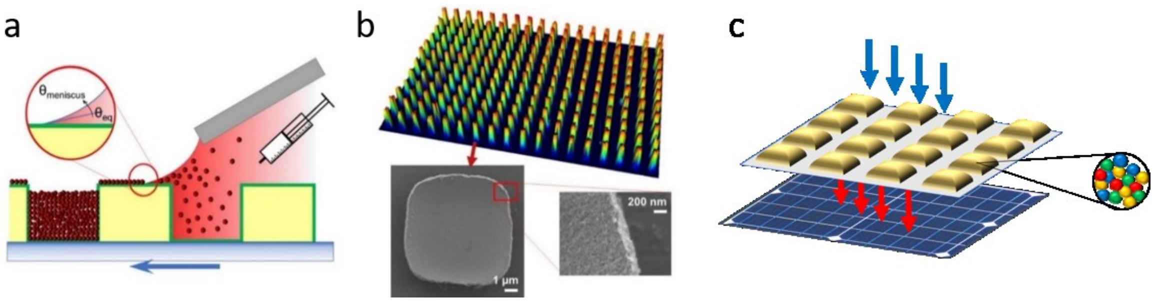

Figure 1: a) operating principle of Convective Self-Assembly on functionalized topographic patterns and with solvent injection, suitable for use with non-polar solvents; b) example of an assembly of nanoparticles (quantum dots of CdSe, 10 nm in diameter) in the form of a matrix of thick microstructures (square patterns, thickness 1.5 µm, lateral size 10 µm, spacing 10 µm) [2]; schematic diagram of a microstructured light conversion layer based on different types of nanoparticles.

Objectives of the thesis

The objective of this thesis is to design and fabricate **3D microstructured light conversion films**, integrating different populations of quantum dots to effectively cover the entire solar spectrum (Fig.1c).

To achieve this goal, the project will revolve around three major axes:

- **Instrumental development**: setting up of an advanced experimental device for CSA deposition in non-polar solvents;
- **Architecture design**: optimizing microstructure geometries to maximize light absorption and conversion;
- **Multi-material assembly**: developping strategies for the controlled organization of several types of nanoparticles within the same structure.

Experimental approach

This thesis will be mainly experimental and will take place in a cleanroom environment. It will combine:

- **Fabrication**: deposition of quantum dots by convective self-assembly on microstructured substrates (photolithography);
- **Advanced characterization**: fluorescence microscopy, optical interferometry, atomic force microscopy (AFM), scanning electron microscopy (SEM);
- **Performance evaluation**: analysis of the optical and conversion properties of the resulting structures.

All the necessary equipment is available in the laboratory.

Candidate profile

- Degree: Master's (M2) or Engineering school degree
- Specialty: Physics, Nanosciences, Nanotechnologies
- Qualities: scientific curiosity and initiative, autonomy and experimental rigor, and a taste for working in an advanced technological environment
- English: good level required (written and oral)

Why choose this project?

- A project **with a high societal impact**, at the heart of current energy challenges
- An approach **at the frontier between physics, nanoscience and engineering**
- The opportunity to work on an **emerging patented technology**
- A rich and multidisciplinary experimental environment

Funding

The thesis is funded by the "Doctoral Allocations on Societal Issues" of INSA Toulouse.

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Bibliographical references

[1] Boniello and Ressier, FR2500658, 2025
[2] Boniello *et al., JCIS,* 2025