2025-2026

Master thesis proposal

Charge carrier dynamics in ZnO nanopowders: influence of oxygen vacancy charge states probed by femtosecond transient absorption spectroscopy

Keywords: ZnO, nanopowders synthesis, oxygen vacancies, defect charge states, transient absorption spectroscopy (TAS), carrier lifetime

Scientific description:

Zinc oxide (ZnO) is a wide–bandgap (3.37 eV) n-type semiconductor whose optical and catalytic properties are largely governed by intrinsic point defects. Among them, oxygen vacancies (V_O) play a central role, existing under various charge states (V_O^0, V_O^+, V_O^{2+}) whose relative populations depend on the synthesis atmosphere and oxygen partial pressure [1,2] which can be identified by their respective emission line measured by photoluminescence (PL) [2]. On the theoretical side, it has been shown by non-adiabatic molecular dynamics that both V_O^+ and V_O^{2+} extend hot-electron lifetimes by acting as trap-assisted recombination centers [3].

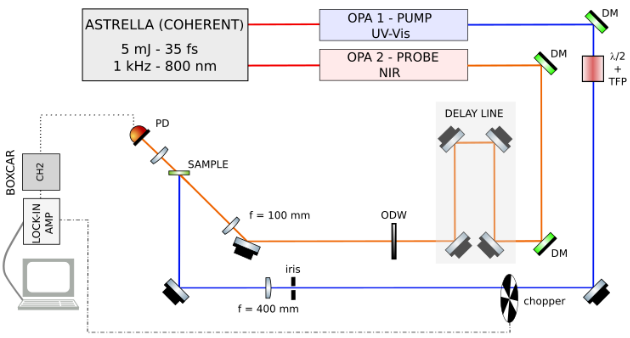

Figure 2. Experimental setup of transient absorption spectroscopy (TAS) on the femtosecond laser platform SUMO @INSP.

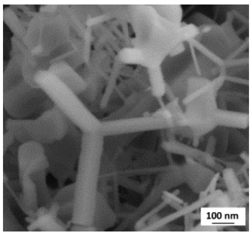

Figure 1. SEM Image of ZnO nanopowder synthesized by GBC in our Lab.

The proposed internship aims to experimentally explore the influence of the vacancy charge state on hot-electron relaxation dynamics, using femtosecond transient absorption spectroscopy (TAS) on the SUMO ultrafast laser platform at INSP. This exploratory stage will: (1) establish a reproducible protocol for sample preparation suitable for TAS measurements from ZnO nanopowders synthesized by glove box combustion (GBC); (2) develop a deposition method ensuring optically homogeneous films of controlled powder thickness on transparent substrates; (3) perform UV–Vis spectroscopy and PL characterizations to correlate optical absorption edges and PL emission bands with defect charge states; (4) conduct first TAS feasibility measurements (pump ≈ 340 nm, probe ≈ 1.3 µm) to compare electron relaxation dynamics for differently reduced/oxidized ZnO samples.
This first step will assess the impact of V_O charge states on hot-electron lifetimes, in direct connection with the published theoretical predictions [3], and define the most promising preparation routes for subsequent systematic studies.

[1] M. Zhang *et al.*, J. Phys. Chem. C **124**, 12696 (2020).
[2] M. Zhang *et al.*, Nanoscale **11**, 5102 (2019).
[3] Y. Yang *et al.*, J. Phys. Chem. Lett. **15**, 1 (2024).

Techniques/methods in use:

Synthesis of ultrapure ZnO nanopowders, UV–Vis and photoluminescence spectroscopy, femtosecond transient absorption spectroscopy (pump–probe).

Applicant skills:
Solid background in condensed-matter or solid-state physics, interest in optical spectroscopy and semiconductor defects. Motivation for experimental work in ultrafast spectroscopy and nanomaterials preparation.
Industrial partnership: N
Internship supervisor(s): Anna Levy (levy@insp.jussieu.fr) – Slavica Stankic (slavica.stankic@insp.jussieu.fr)
Internship location: Institut des Nanosciences de Paris, 4 Place Jussieu, 75005 Paris.
Possibility for a Doctoral thesis: Y