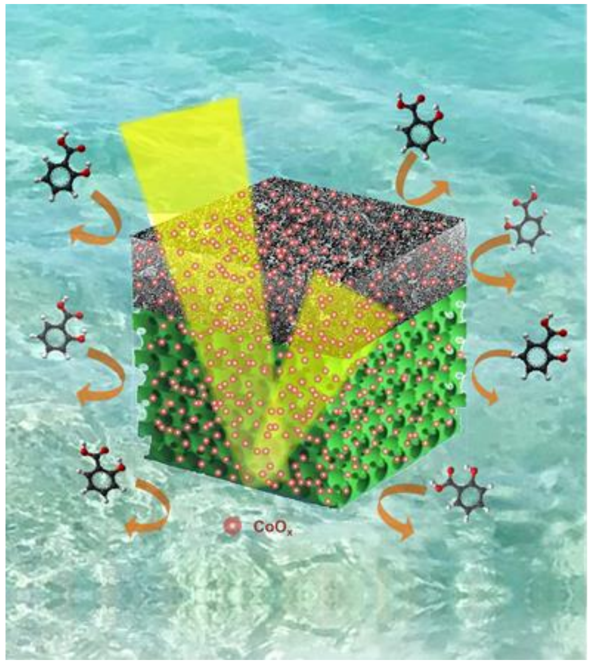
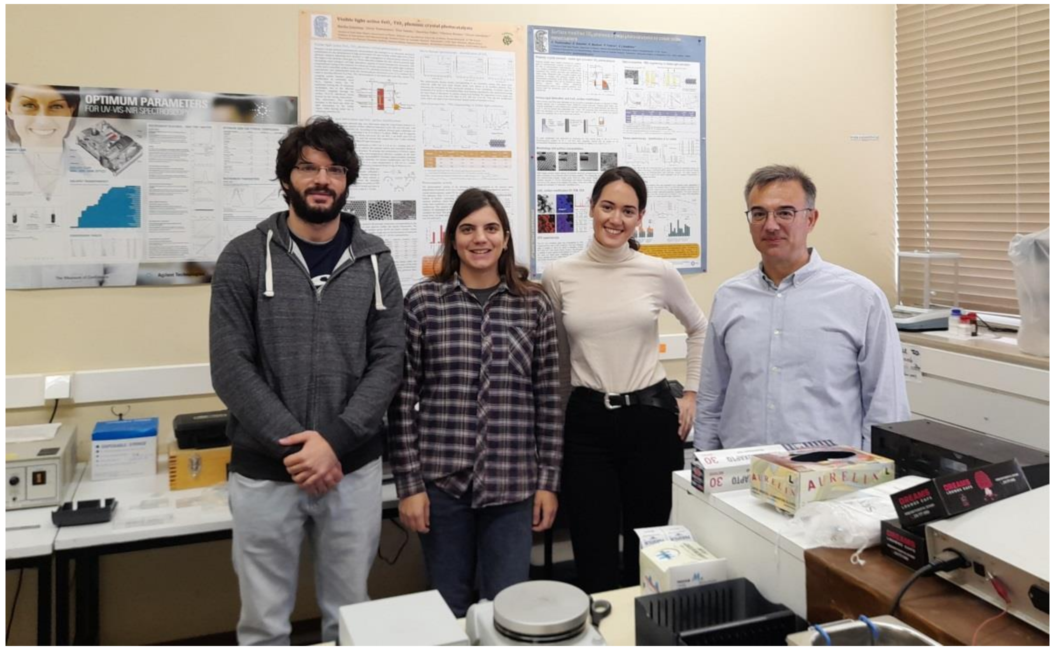
Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment



Title of the research project:
Advanced photocatalytic Slow Photon nanostructures

Principal Investigator:
Vlassis Likodimos
Reader-friendly title:
SLOWPHOTON
Scientific Area:
Engineering Sciences &Technology
Institution and Country:
National and Kapodistrian University of Athens, Greece
Host Institution:
National and Kapodistrian University of Athens
Collaborating Institutions:
NCSR “D”, NTUA, University of Cincinnati, University of Porto



Budget: **190,000.00 €**

Duration: **36 months**

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Research Project Synopsis

SLOWPHOTON aims at the development of innovative photocatalytic photonic nanostructures featuring unprecedented advancements in visible light trapping by slow photons and charge separation of photocatalytic materials. The project adopts a hierarchical approach for the development of single/multilayer photocatalytic films building upon the combination of advanced slow photon engineering with targeted compositional and electronic modifications to tailor charge separation and visible light activation of photocatalytic nanomaterials. To this aim, monolithic photonic crystals in the form of macro-mesoporous inverse opals with controlled optical properties will be developed by heterostructuring titania with nanoscopic metal (Fe, Co) oxides (solar environmental catalysts) and two dimensional MoS_2 dichalcogenides as well as by using $BiVO_4$ as alternative, environmentally friendly, visible light activated photocatalyst, independently or in combination with plasmonic metal nanoparticles. These innovative nanostructures will be applied as building blocks for multilayer photonic stacks in the form of unconventional cavity resonators enabling slow photon backscattering and resonant circulation. Alternatively, they will be modified by planar defect layers or refractive index grading for the spectral enhancement of slow light and the reduction of Bragg losses. Comparative evaluation of the materials' photocatalytic efficiency, stability and reusability will be performed for water detoxification on classical water contaminants such as phenol but also microcystins and contaminants of emerging concern such as diclofenac and macrolide antibiotics listed in EU-Decision 2015/495. Structure-activity relations will be interactively investigated combining morphological, structural and optoelectronic characterization and theoretical modeling as well as determination of the underlying reactive oxygen species in order to optimize materials performance. A major technological outcome will be pursued by the up-scaled deposition of the most efficient photonic films on ceramic membranes that will be incorporated in a continuous flow photocatalytic membrane reactor for the implementation of sustainable hybrid water treatment technology based on the integration of photonic materials to membrane technology.

Project originality

SLOWPHOTON will follow novel strategies to improve photocatalytic materials aiming at the development of *photocatalytic photonic nanostructures* that feature major advancements in the efficiency of visible light trapping by slow photons and charge separation. The project adopts a hierarchical approach for the design and development of innovative single/multilayer photocatalytic films building upon the combination of slow photon engineering with targeted compositional modifications of the nanocatalysts. SLOWPHOTON will explore new frontiers of knowledge and will deliver key improvements in photon capture and photocatalytic materials relying on an integrated approach and the complementary skills and expertise of three Greek (NKUA, NCSR"D", NTUA) and two international (FEUP-Portugal, UC-USA) partners in material science and nanotechnology, photocatalytic processes and membrane technology that join forces toward the common goal of improved photocatalytic materials and technologies for environment protection via advanced photon management. This ambitious project is based on the coordinated implementation of the following breakthrough scientific and technological objectives:

- *Surface modification of photonic band gap (PBG) engineered TiO_2 inverse opals by nanoscale Fe, Co oxides for the development of innovative solar environmental catalysts.*
- *Controlled fabrication of metal doped $BiVO_4$ inverse opals as environmentally friendly alternatives to traditional TiO_2-based VLA photocatalysts.*
- *Heterostructuring of TiO_2 inverse opals by MoS_2 nanoplatelets as highly efficient electron scavengers and broadband visible light sensitizers.*
- *Noble metal (Au, Ag) grafting on selected PBG engineered inverse opals for synergistic visible light harvesting by localized surface plasmon resonance (LSPR) with slow photons.*
- *Multilayer PBG engineered VLA inverse opals and planar defect/graded fabrication for slow photon back scattering, resonant circulation and spectral enhancement.*
- *Evaluation of materials activity, stability, reusability and reaction mechanism on water pollutant photodegradation.*
- *Up-scaled deposition of selected photonic films on ceramic membranes and incorporation in a continuous flow membrane photoreactor for hybrid water treatment.*

Expected results & Research Project Impact

The overall strategy of SLOWPHOTON involves the development and uptake of innovative photocatalytic photonic nanostructures for application in solar light driven processes and technology. Achievement of the project goals will have high impact by reinforcing scientific knowledge on advanced photocatalytic materials and solar photocatalysis technologies to regional and international sustainable development. Most of the project objectives will be explored for the first time offering the prospect to "leapfrog" light harvesting and efficiency of photocatalytic materials. In addition to the project novelty, SLOWPHOTON proposes the use of environmentally friendly (non-toxic, earth abundant) materials as key components of the novel photonic photocatalysts, an issue that has been overlooked in previous studies, while it has strong societal impact by supporting the development of advanced technologies for water purification by hazardous organic substances such as cyanotoxins and water contaminants of emerging concern including diclofenac and macrolide antibiotics (EU-Decision 2015/495). Besides enriching knowledge in the academic level, the project will deliver major advancements in the development of VLA photocatalysts, which are expected to play pivotal role to the projected photocatalyst's market. Specifically, a major factor for the future growth of photocatalytic products is the introduction of visible-light responsive photocatalysts, which are ideally suited for indoor applications or artificial lightning like antimicrobial surfaces and coatings, where the project is expected to provide major advances.

SLOWPHOTON has also the potential to augment knowledge on hybrid photocatalytic membranes, a rather new application area that can radically promote photocatalytic water purification. Step up changes in water treatment technologies can be thus envisaged in terms of both improving treatment performance and reducing energy requirements that could attract the attention of drinking water and environmental industries. Furthermore, the ensuing progress can be leveraged to other technologies, such as air purification, water splitting and H_2 production, sensors and solar cells.

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The importance of this funding

H.F.R.I. funding of SLOWPHOTON gave me the opportunity to design and mainly implement an ambitious research project aimed at developing advanced photonic nanostructures at the edge of current scientific research in photocatalytic materials. This proposal is based on the combination of photocatalytic nanomaterials with photonic crystals, long established as prototype periodic structures to control light propagation and enhance light- matter interactions, supporting a new research activity at the Department of Physics of NKUA. Funding from H.F.R.I. ensures the successful implementation of SLOWPHOTON concerning the synthesis of a numerous single- and multi-layered photonic films and their photocatalytic evaluation with extensive requirements in laboratory consumables and equipment as well as human resources, especially doctoral candidates who are given the opportunity to work on a topical subject that attracts high scientific and technical interest.

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