Executive Summary:
Heterogeneous photocatalysis is potentially one of the cheapest and most efficient methods for decontamination of water and air from toxic organic pollutants since highly oxidizing conditions can be established without any further reagents needed – the only prerequisite is the supply of aerobic oxygen and sunlight irradiation. Nevertheless, real-life applications of photocatalysis are still rather scarce, particularly because the photocatalytic degradation rates are not high enough, and the costs associated with the photoreactor construction make the implementation economically unviable. The project 4G-PHOTOCAT (www.4g-photocat.eu) therefore allied the expertise of 7 academic and 3 industrial partners from 5 EU countries (Germany, United Kingdom, Czech Republic, Poland, and Finland) and 2 ASEAN countries (Malaysia and Vietnam) for the development of a novel generation of low-cost nano-engineered photocatalysts for sunlight-driven water depollution.

Through rational design of composites in which the solar light-absorbing semiconductors are coupled to nanostructured redox cocatalysts based on abundant elements, the recombination of photogenerated charges is suppressed and the rate of photocatalytic reactions is enhanced. Within this project, large sets of highly active, novel composite photocatalysts based on commercially available TiO2 powders (used as benchmark starting materials) coupled to low-cost redox cocatalysts have been developed and tested, exhibiting enhanced activities (by factors of 2 to 7) as compared to conventional benchmark TiO2 photocatalysts. Furthermore, protocols have been developed by an industrial partner (Advanced Materials JTJ) for implementation of the photocatalysts into a liquid paint, allowing for deposition of robust photoactive layers onto flat surfaces. In addition, several types of novel photocatalytic reactors have been designed and developed. Such photoreactors based on paintable coatings have been successfully tested under real-sunlight conditions, and they are envisaged as low-cost devices for detoxification of water from highly toxic persistent organic pollutants in remote rural areas of Vietnam and other countries.
In order to achieve fabrication of optimal nanostructures, advanced chemical deposition tools have been developed. Design and optimization of new ALD (Atomic Layer Deposition) reactor constructions was performed by Picosun. These ALD reactor constructions for modification of larger amounts of powder materials were developed in the project and they are already in industrial use at several customer sites.

Apart from the synergy on the industrial level, the specific EU-ASEAN cooperation within 4G-PHOTOCAT offered unique opportunity of intensified collaboration and mutual scientific exchange between scientists from EU and ASEAN countries. Biannual meetings and short-term research exchange visits were practised in order to assure fast progress within the project. Two conferences in Asia (Bangkok, Thailand; Johor, Malaysia) on photocatalysis have been organized. The cooperation networks established within 4G-PHOTOCAT represent a platform for a long-standing scientific exchange and cooperation. The project provided funding for 48 young investigators in the early stage of their career (PhD students and postdocs) who have had the opportunity to visit other partners' labs and obtain valuable scientific and intercultural experiences. This intense exchange is expected to lead to further cooperation in further collaborative projects in the future.

Project Context and Objectives:

People from many countries of the world extensively use pesticides which contaminate drinking and irrigation water with toxic organic compounds. For example, in rural areas of Vietnam, herbicides and dioxins, which are resistant to degradation, made their way into the water cycle during the Vietnam war. Cancer and abnormalities in newborns can be the consequence.

Heterogeneous photocatalysis is potentially one of the cheapest and most efficient methods for decontamination of water from toxic organic pollutants since highly oxidizing conditions can be established without any further reagents needed – the only prerequisite is the supply of aerobic oxygen and sunlight irradiation. Nevertheless, real-life applications of photocatalytic water treatment are still rather scarce, particularly because the photocatalytic degradation rates are not high enough, and the costs associated with the photoreactor construction make the implementation economically unviable. It is well-established that low reaction rates are mainly caused by low quantum yields of photocatalytic reactions (few per cent), meaning that most of the photogenerated charges in the photocatalyst recombine before inducing the desired redox reactions. In particular, the reduction of oxygen by photogenerated electrons is highly important and represents often the limiting step in photocatalytic degradation reactions.

The main scientific objective of the 4G-PHOTOCAT project was to develop a novel generation of low-cost nanoengineered photocatalysts for sunlight-driven water depollution. The newly developed photocatalysts are titanium dioxide particles coupled to nanostructured redox co-catalysts based on cheap and abundant elements. In the presence of the co-catalysts the rate of oxygen reduction reaction is enhanced, which suppresses the recombination of photogenerated charges, and leads to enhanced rates of photocatalytic reactions. In order to achieve fabrication of optimal architectures, advanced chemical deposition techniques with a high degree of control over composition and morphology are being employed and further developed.

The main technological objective of 4G-PHOTOCAT was to develop a highly active composite photocatalyst based on cheap and abundant elements, and to implement it into a liquid paint, allowing for the deposition of robust photoactive layers onto various surfaces on a large scale. Such paintable photoreactors are envisaged as low-cost devices for sunlight-driven detoxication of irrigation as well as drinking water from highly toxic persistent organic pollutants (POPs) in remote rural areas of Vietnam and other countries.

In order to accomplish these objectives, the 4G-PHOTOCAT project allied the expertise of seven academic and three industrial partners from five EU countries and two Southeast Asian countries.

The 4G-PHOTOCAT project is divided into eight main work-packages plus two WPs for financial and administrative management (WP9), and other activities (WP10). The work-packages were designed in order to ensure smooth workflow from fabrication of novel composite photocatalysts (WP1, WP2, WP3, WP4), their implementation into a paint (WP5), investigating their photocatalytic activity and photochemical/photophysical properties (WP6), supported by theoretical calculations (WP7), to quasi-field tests of detoxication of POP contaminated water in painted photoreactors under real-sunlight irradiation in Vietnam (WP8).

Project Results:
The main achievements of the 4G-PHOTOCAT project in various work packages are described below.

WP1 (Precursor synthesis) and WP2 (ALD processing)

Precursors for atomic layer deposition (ALD) have been synthesized and delivered. Pristine and cocatalyst-modified TiO2 films have been fabricated by ALD and successfully used in photocatalytic testing as model systems. The photocatalytic properties of these model systems have been studied.

A new ALD process for deposition of copper oxide using Cu(dmap)2 and ozone was developed and published. Thin films were grown at low deposition temperatures between 80 and 140 °C with a growth rate of 0.2–0.3 Å/cycle. The deposited CuO films were relatively
smooth and contained low amount of impurities regardless that the films were grown at low deposition temperatures.

WP3 (ALD reactor development)

Design and optimization of new POCA™ (powder cartridge) ALD reactor constructions for up to hundreds of grams of powders was performed. Simulation of the flow conditions using computational fluid dynamics in complex systems for ALD of powders was also done and it gave valuable knowledge especially for the development of POCA™ systems. The POCA™ construction, especially combined with PicoVibe™, was found to be the best option for upscaling of powders in the present reactor frames of Picosun™ reactors. The new POCATM constructions with PicoVibeTM designed and tested in the project for the modification of larger amounts of powders are already in industrial use at Picosun's customers' sites. The project thus enabled expansion of ALD technology for new industrial applications.

WP4 (Fabrication of photocatalysts) and WP6 (Photocatalytic tests)

Large sets of highly active, novel composite photocatalysts based on commercially available TiO2 powders (used as benchmark starting materials) coupled to low-cost redox cocatalysts have been developed, tested, and investigated in terms of mechanism of photocatalytic performance. These included, for example, TiO2 modified with Fe2O3 cocatalyst by photochemical deposition technique, exhibiting photocatalytic degradation rates enhanced by the factor of 2.2 as compared to pristine P25 TiO2 materials. Another highly active photocatalysts have been obtained by deposition of CuO cocatalyst using a novel rapid microwave solvothermal technique. It was found that a residence time of just five minutes was enough to form crystalline CuO particles in high yield (>80%) using copper(II) acetate hydrate precursor in ethanol solvent at 150 °C, a grey appearance which darkened upon Cu loading. XRD confirmed CuO as the crystalline product from the reaction. These materials exhibited enhanced photocatalytic degradation rates as compared to P25 (enhancement factor of 1.5).

Another example of newly developed photocatalysts is represented by rutile TiO2 materials impregnated with single Cu(II) and Fe(III) cocatalytic sites. Due to the single-ion nature of the redox cocatalytic sites, the parasitic light absorption by the cocatalyst is minimized and the materials exhibit highly enhanced rates in photocatalytic degradation of organic aqueous pollutants, achieving degradation rates comparable to TiO2 modified with noble metals like Pt. The exact mechanism of the photoactivity enhancement differs depending on the nature of the cocatalyst. Cu(II)-decorated samples exhibit fast transfer of photogenerated electrons to Cu(II/I) sites, followed by enhanced catalysis of dioxygen reduction, resulting in improved charge separation and higher photocatalytic degradation rates. At Fe(III)-modified rutile the rate of dioxygen reduction is not improved and the photocatalytic enhancement is attributed to higher production of highly oxidizing hydroxyl radicals produced by alternative oxygen reduction pathways opened by the presence of catalytic Fe(III/II) sites. Importantly, the single isolated ion nature of the catalytic sites makes this type of materials distinct from more conventional visible light-active modified TiO2 or TiO2 composites with heterojunction structure, and also from "single site photocatalysts" based on light-absorbing metal ion species dispersed on the surface of zeolites or silica. As the photocatalytic activity of most photocatalysts is known to be highly substrate-specific and depending also on a complex interplay of many material properties (crystallinity, porosity, surface area, relative amounts of specific crystal facets, etc.), the demonstrated variety of mechanisms of photoactivity enhancement at single site catalyst-modified photocatalysts holds promise for developing many novel, tailored photocatalysts for various applications.

WP5 (Photocatalyst paint coatings)

The paintable coatings produced by Advanced Materials JTJ have been further developed. The coatings parameters meet requirement of photocatalyst coatings painted onto substrates exhibit long-term (> 2 weeks) stability in aqueous media under irradiation. The coatings are capable of a long-term existence in aqueous environment on most of the common materials while preserving the photocatalytic efficiency.

Bulk quantities of the commercially available TiO2 coatings were produced and shipped to project partners in Vietnam for the pilot reactor testing. The amount of materials (250 liters) was suitable to run the large reactors for several months and treat 2 000 000-10 000 000 liters of contaminated water. Several personal visits were arranged at HUA and Q&A to help with the experimental design on site.

Synergies of the new compositions with functionalized binding systems were designed and investigated. Hundreds of development compositions of photocatalytic coatings with multifunctional binders were prepared. Samples of the selected compositions were provided to the partners for performance characterization. Durability and photocatalytic performance of the compositions were tested. In the final stage of the project, bulk quantities of photocatalyst paint coatings based on newly developed composite photocatalysts were produced and transferred to partners in Vietnam for the pilot reactor testing.
WP7 (Theoretical calculation)

Several different metal-oxide systems were studied. The bulk band structure of these materials was calculated, and experimental data were used to determine what the relative positions of the band edges are. The effects of sensitization of anatase TiO₂ with Fe₂O₃ clusters on the reaction chemistry were studied (based on realistic low energy (Fe₂O₃)ₙ clusters, particularly their reaction chemistry with the (101) surface and the mechanisms of charge transfer from the anatase TiO₂ to the iron oxide material. Furthermore, the effects of single ion transition metal cocatalysts, specifically Cu(II) and Fe(III), on the charge separation properties of rutile TiO₂-(110) surfaces was investigated, providing valuable confirmation of experimental mechanistic insights. In addition, the degradation processes of the volatile organic compounds during photocatalysis have been modelled.

WP8 (Quasi-field photoreactor testing)

Several new devices and techniques for solar photocatalytic detoxication of drinking and irrigation water have been developed and tested. Screening of contaminated sites and relevant pollutants in Vietnam has been carried out. Quasi-field solar experiments of solar photocatalytic purification of real water have been performed and evaluated. At the J. Heyrovský Institute of Physical Chemistry, Prague, Czech Republic, advanced research has been performed including design, construction and testing of pilot solar photoreactors for decontamination of drinking water and semi-field solar decontamination of surface water by floating photocatalysts. At the Vietnam National University of Agriculture, investigation of solar photocatalysis has been realized including the design, construction and testing of solar photoreactors for decontamination of drinking water. Several photoreactors have been developed and installed at the Vietnam National University of Agriculture in Hanoi, Vietnam. Also solar decontamination of surface water by floating photocatalysts has been successfully tested. Parameters like suitability of different support materials, commercial as well as newly-developed for the photocatalytic coating and investigation of various factors influencing the photoefficiency (such as aeration, surface area of the photocatalytic coating, thickness of the photocatalytic layer, durability of the photocatalytic paint) has been investigated. Experimentation with mirrors led to the enhancement of solar efficiency by factor of 1.3. The enhancement of degradation rates in quasi-field tests using newly developed composite photocatalysts was ca. 1.2 so far (painted coatings based on modified TiO₂ vs. benchmark TiO₂ paint). However, it should be noted that several composite photocatalysts newly developed within 4G-PHOTOCAT have shown much more enhanced degradation rates (by factors 2-7) in laboratory testing. Accordingly, further experimental efforts in quasi-field testing are expected to yield comparable enhancement factors.

Two different photoreactors for solar photocatalytic decontamination of drinking water and one photoreactor for standard tests of photocatalytic activity will be protected as utility models.

Potential Impact:

The main scientific objective of 4G-PHOTOCAT was to develop novel composite photocatalysts with enhanced efficiency and to understand the correlation between compositional and structural properties of the nanostructured composite, and the photocatalytic reaction rates and degradation mechanisms under solar irradiation. The main technological objective of 4G-PHOTOCAT was to develop paintable photoreactors that will be utilized as low-cost devices for sunlight-driven detoxification of water from highly toxic persistent organic pollutants (POPs) in remote rural areas of Vietnam and other countries. The application of the low-cost painted photocatalytic reactors for water decontamination in remote rural areas of Vietnam and elsewhere will in middle and long term lead to improvement of health standards of poor and underprivileged people based in areas affected by the overuse of herbicides and other toxic organic substances.

Moreover, the composite photocatalysts developed within 4G-PHOTOCAT find use also in other photocatalytic applications including cleaning of air or solar fuel production, as already exemplified by several publications from the 4G-PHOTOCAT the consortium. It should be noted that novel routes for synthesis of metal oxide nanomaterials, their advanced characterization and better understanding developed within 4G-PHOTOCAT are expected to have a major impact on nanotechnology in general, with possible repercussions on sectors of catalysis, health, environment, energy and transport.

Three different types of newly developed photocatalytic reactor constructions will be protected by utility models.

The 4G-PHOTOCAT consortium contains three industrial partners all of which are eager to pick up the technological progress of the project for future commercialisation.

Picosun, a well-established developer of unique ALD reactors, has developed both up-flow (fluidized bed, PicoFloatTM) and down-flow (powder cartridge, POCA PTM) designs for Picosun® ALD reactors for powders. The new POCA PTM constructions with PicoVibeTM designed and tested in the project for the modification of larger amounts of powders are already in industrial use at Picosun’s customers’ sites. The project thus enabled expansion of ALD technology for new industrial applications.
Advanced Materials, the SME based in the Czech Republic running production of photocatalytic coatings has already established cooperation with Q&A Ha Noi, a small Vietnamese SME founded in order to introduce nanotechnologies to the Vietnamese market. Showing the feasibility of water remediation using paintable photoreactors achieved within 4G-PHOTOCAT will for both partners lead to enhancements of product portfolio (photocatalytic coating applicable in aqueous media) and increase of sales. Moreover, 4G-PHOTOCAT provides for AM and Q&A enhanced visibility on the highly important market segment of Asian region. This is crucially important since, due to increasing environmental concerns, the market for photocatalytic environmental applications is expected to boom within the next 10 years. Advanced Materials has been selected as a National Champion representing Czech Republic in the 2015/2016 European Business Awards.

EU-ASEAN cooperation

Apart from the above-mentioned synergy on the industrial level, the specific EU-ASEAN cooperation within 4G-PHOTOCAT offered unique opportunity of intensified collaboration and mutual scientific exchange between scientists from EU and ASEAN countries. Biannual meetings and short-term research exchange visits were practised in order to assure fast progress within the project. Two conferences in Asia (Bangkok, Thailand; Johor, Malaysia) on photocatalysis have been organized. The cooperation networks established within 4G-PHOTOCAT represent a platform for a long-standing scientific exchange and cooperation. The project provided funding for 48 young investigators in the early stage of their career (PhD students and postdocs) who have had the opportunity to visit other partners’ labs and obtain valuable scientific and intercultural experiences. This intense exchange is expected to lead to further cooperation in further collaborative projects in the future.

Conferences organized:

- The 12-months meeting was organized (together with LIMPID and PCATDES consortia) in conjunction with a joint workshop on photocatalysis (over 60 participants) within the EU-ASEAN STI Days in Bangkok (21.-23.01.2014).
- The final meeting was organized in conjunction with a joint One Day EU-ASEAN Symposium and Workshop on Photocatalysis in Johor, Malaysia, on 24.11.2015 (over 60 participants).

Engaging with civil society and policy makers

4G-PHOTOCAT members have actively participated in the European Cluster on Catalysis, a coordination and advisory body for the European Commission in the field of catalysis within the Horizon 2020 framework, gathering together EU-funded projects in the field of catalysis, as well as other academic and industrial stakeholders in catalysis at EU level.

Scientific peer-reviewed publications

The project has resulted in 32 peer-reviewed publications so far (as of February 2016; the list of 4G-PHOTOCAT publications will be in future continuously updated at [www.4g-photocat.eu](http://www.4g-photocat.eu)).


“Highly Efficient Rutile TiO2 Photocatalysts with Single Cu(II) and Fe(III) Surface Catalytic Sites”

(30) H. O. Lintang, N. A. Roslan, N. Ramlan, M. Shamsuddin, L. Yuliati
“Photocatalyst Composites of Luminescent Trinuclear Copper(I) Pyrazolate Complexes/Titanium Oxide for Degradation of 2,4-Dichlorophenoxyacetic Acid”

"Modification of Titanium Dioxide Nanoparticles with Copper Oxide for Photocatalytic Degradation of 2,4-Dichlorophenoxyacetic Acid"


"Size controlled TiO2 nanoparticles on porous hosts for enhanced photocatalytic hydrogen production"

(27) X. An, T. Li, B. Wen, J. Tang, Z. Hu, L. Liu, J. Qu, C.P. Huang, H. Liu
"New Insights into Defect-Mediated Heterostructures for Photoelectrochemical Water Splitting"

(26) T. Iivonen, J. Hämmäläinen, B. Marchand, K. Mizohata, M. Mattinen, G. Popov, J. Kim, R. A. Fischer, M. Leskelä
"Low Temperature Atomic Layer Deposition of Copper(II) Oxide Thin Films"

"Fabrication of Gold/Titania Photocatalyst for CO2 Reduction Based on Pyrolytic Conversion of the Metal–Organic Framework NH2-MIL-125(Ti) Loaded with Gold Nanoparticles"

(24) M. Buchalska, M. Kobielusz, A. Matuszek, M. Pacia, S. Wojtyla W. Macyk
"On Oxygen Activation at Rutile- and Anatase-TiO2"

(23) W. R. Siah, H. O. Lintang, M. Shamsuddin, L. Yuliati
"Effect of calcination temperatures on the photocatalytic activities of commercial titania nanoparticles under solar simulator irradiation"

(22) S. J. A. Moniz, C. S. Blackman, P. Southern, P. M. Weaver, J. Tang, C. J. Carmalt
"Visible-light driven water splitting over BiFeO3 photoanodes grown via the LPCVD reaction of [Bi(OtBu)3] and [Fe(OtBu)3]2 and enhanced with a surface nickel oxygen evolution catalyst"
Nanoscale 2015, 39, 16343-16353.

(21) D. J. Martin, G. Liu, S. J. A. Moniz, Y. Bi, A. M. Beale, J. Ye, J. Tang
"Efficient visible driven photocatalyst, silver phosphate: performance, understanding and perspective"

(20) S. J. A. Moniz, J. Tang
"Charge Transfer and Photocatalytic Activity in CuO/TiO2 Nanoparticle Heterojunctions Synthesised through a Rapid, One-Pot, Microwave Solvothermal Route"
This paper has been featured on the journal front Cover page
4G-PHOTOCAT funding has been highlighted in the Cover profile

(19) S. Ho-Kimura, S. J. A. Moniz, J. Tang, I. P. Parkin
"A Method for Synthesis of Renewable Cu2O Junction Composite Electrodes and Their Photoelectrochemical Properties"

(18) N. A. Roslan, H. O. Lintang, L. Yuliati
"Enhanced Performance of Copper-Modified Titanium Dioxide Prepared by UV Reduction Method"
(17) W. R. Siah, N. A. Roslan, H. O. Lintang, M. Shamsuddin, L. Yuliati
"Photocatalytic Removal of 2,4-D Herbicide on Lanthanum Oxide-Modified Titanium Dioxide"

(16) O. V. Khavryuchenko, L. Wang, D. Mitoraj, G. H. Peslherbe, R. Beranek
"Enabling visible-light water photooxidation by coordinative incorporation of Co(II/III) cocatalytic sites into organic-inorganic hybrids: quantum-chemical modeling and photoelectrochemical performance"

(15) H. M. Stewart, S. A. Shevlin, C. R. A. Catlow, Z. X. Guo
"Compressive Straining of Bilayer Phosphorene Leads to Extraordinary Electron Mobility at a New Conduction Band Edge"

(14) M. Buchalska, M. Surówka, J. Hämäläinen, T. Ivonen, M. Leskelä, W. Macyk
"Photocatalytic activity of TiO2 films on Si support prepared by atomic layer deposition"

(13) S. J. A. Moniz, S. A. Shevlin, D. J. Martin, Z.-X. Guo, J. Tang
"Visible-light driven heterojunction photocatalysts for water splitting – a critical review"

(12) P. Chen, P. Wang, L. Wang, A. Kostka, M. Wark, M. Muhler, R. Beranek
"CNT-TiO2-d composites for improved co-catalyst dispersion and stabilized photocatalytic hydrogen production"

(11) X. An, H. Liu, J. Qu, S. J. A. Moniz, J. Tang
"Photocatalytic mineralisation of herbicide 2,4,5-Trichlorophenoxyaceticacid: Enhanced performance by triple junction Cu-TiO2-Cu2O and the underlying reaction mechanism"

(10) C. Jiang, S. J. A. Moniz, M. Khraisheh, J. Tang
"Earth-Abundant Oxygen Evolution Catalysts Coupled onto ZnO Nanowire Arrays for Efficient Photoelectrochemical Water Cleavage"

(9) M. Buchalska, M. Pacia, M. Kobielszcz, M. Surówka, E. Swietek, E. Wlazlak, K. Szczaciłowski, W. Macyk
"Photocatalytic Activity of TiO2 Modified with Hexafluorometallates—Fine Tuning of Redox Properties by Redox-Innocent Anions"

"Fe2O3–TiO2 Nanocomposites for Enhanced Charge Separation and Photocatalytic Activity"

(7) X. Han, H. M. Stewart, S. A. Shevlin, C. R. A. Catlow, Z. X. Guo
"Strain and Orientation Modulated Bandgaps and Effective Masses of Phosphorene Nanoribbons"

(6) M. Bledowski, L. Wang, S. Neubert, D. Mitoraj, R. Beranek
"Improving the Performance of Hybrid Photoanodes for Water Splitting by Photodeposition of Iridium Oxide Nanoparticles"

(5) D. J. Martin, P. J. T. Reardon, S. J. A. Moniz, J. Tang
"Visible light-driven pure water splitting by a nature-inspired organic semiconductor based system"
(4) S. M. Ho-Kimura, S. J. A. Moniz, A. D. Handoko, J. Tang
"Enhanced photoelectrochemical water splitting by nanostructured BiVO4-TiO2 composite electrodes"

(3) X. An, J.C. Yu, J. Tang
"Biomolecule-assisted fabrication of copper doped SnS2 nanosheet-reduced graphene oxide junctions with enhanced visible-light photocatalytic activity"

(2) S. Neubert, P. Pulisova, C. Wiktor, B. Mei, D. A. Guschin, R.A. Fischer, M. Muhler, R. Beranek
"Enhanced photocatalytic degradation rates at rutile TiO2 photocatalysts modified with redox co-catalysts"

(1) S. Neubert, A. Ramakrishnan, J. Strunk, H. Shi, B. Mei, L. Wang, M. Bledowski, D. A. Guschin, M. Kauer, Y. Wang, M. Muhler, R. Beranek
"Surface-Modified TiO2 Photocatalysts Prepared by a Photosynthetic Route: Mechanism, Enhancement, and Limits"

Publications in professional magazines

(2) S. Ożóg
"Fotokatalityczna degradacja herbicydów – nowe katalizatory na bazie TiO2"
Wiadomości Chemiczne 2015, 69 (7-8), 605–616.

(1) R. Beranek, S. Neubert
"Chemie unter der Sonne: Neue photoaktive Materialien für Energiekonversion und Umweltschutz"
GIT Labor-Zeitschrift 2014, 58/3, 72-75.

Talks & conference contributions:

140 conference contributions (for the full list see www.4g-photocat.eu)

4G-PHOTOCAT posters have been awarded two Best Poster Prizes at international conferences:

SP-4, "4th International Conference on Semiconductor Photochemistry", Prague (Czech Republic), 23.-27.06.2013

IPS-20, "20th International Conference on the Conversion and Storage of Solar Energy", Berlin (Germany), 27 July – 1 August 2014

Theses and Dissertations:

4G-PHOTOCAT research has resulted in ten bachelor, master, and PhD theses so far:

• Master thesis: "Synthesis and characterization of TiO2 photocatalysts modified with redox co-catalysts" by Manuel Heimann at Ruhr-Universität Bochum, Germany (13.10.2014).
• Master thesis: "Degradation of methylene blue on commercial photocatalysts under solar light" by Nguyen Thi Thoa at HOC VIEN NONG NGHIEP VIET NAM (30.11.2015).
• Master thesis: "Investigating factors effect on photoactivity of commercial TiO2 (FN2)" by Nguyen Le Thuy at HOC VIEN NONG NGHIEP VIET NAM (30.06.2015).
• Bachelor thesis: "Controlled Deposition of Redox Cocatalysts onto Anatase TiO2 for Water Remediation" by Alina Gawel at Ruhr-Universität Bochum, Germany (30.07.2015).
• PhD Thesis: "Interface Engineering of Photocatalysts for Water Decontamination and Artificial Photosynthesis of Fine Chemicals"
• Master thesis: "Preparation and characterization of iron modified TiO2 photocatalysts utilizing a [Fe(NH3)6]2+-complex" by Annika Diekmann at Ruhr-Universität Bochum (December, 2015).
• PhD Thesis: Title to be announced; by Jiyeon Kim at Ruhr-Universität Bochum (expected in December, 2016).
• PhD Thesis: Tentative title: "Atomic Layer Deposition of Transition Metal Oxide Thin Films for Photocatalytic Application" by Tomi Iivonen (University of Helsinki); (expected in December, 2016).

Further Dissemination Activities

Further dissemination activities included press releases, numerous TV, radio, and press coverages, distribution of flyers, and presentations of 4G-PHOTOCAT at large interactive events including EuroNanoForum 2013 in Dublin, Ireland (18.-20.06.2013). and EuroNanoForum 2015 in Riga, Latvia (10.-12.06. 2015). A few selected dissemination results are listed below:
• A short article Zavádění fotokatalýzy do každodenního života published on the web of Akademický bulletin in Czech republic.
• On April 6th the project has been presented in TVP Kraków (Polish regional television) in "Kronika" magazine. The link to the record is here (it starts at 12:35 of the record).
• A web article prepared by the Centre for Innovation, Technology Transfer and University Development (CITTRU) of JUK (18.03.2013).
• The concrete answer to pollution by Horizon – The EU Research & Innovation Magazine (18.12.2014).

List of Websites:
Project webpage: www.4g-photocat.eu

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