UNIVERSITÀ DEGLI STUDI DI MILANO

TO MAGNIFICO RETTORE OF UNIVERSITA' DEGLI STUDI DI MILANO **ID CODE 4756**

I the undersigned asks to participate in the public selection, for qualifications and examinations, for the awarding of a type B fellowship at **Dipartimento di Chimica**

Scientist- in - charge: Prof. Gian Luca Chiarello, Prof.ssa Elena Selli

[Annalisa Polo]

CURRICULUM VITAE

PERSONAL INFORMATION

Surname	Polo
Name	Annalisa
Date of birth	29, March, 1990

PRESENT OCCUPATION

Appointment	Structure
PhD student in Chemistry (3° year)	Chemistry Department, University of Milan, Milan (Italy)

EDUCATION AND TRAINING

Degree	Course of studies	University	year of achievement of the degree
Degree	Bachelor Degree in Chemistry (L-27)	University of Padua, Italy	2013
Degree	Master Degree in Chemistry (LM-54)	University of Padua, Italy	2016
Post-Graduate Research Fellowship	Coherent 2D Electronic Spectroscopy methods development	Universität Würzburg, Germany	2016
Post-Graduate Research Fellowship within the "SmartMatLab Project" funded by Fondazione Cariplo and Regione Lombardia	Synthesis, photoelectrochemical and spectroscopic characterization of semiconductor photocatalysts for solar fuels applications	University of Milan, Italy	2017
PhD	Chemistry	University of Milan	2021 (Expected)
Visiting researcher in the Laboratory for Molecular	Development and photoelectrochemical	Institute of Chemical Sciences and Engineering,	2019

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Engineering of Optoelectronic Nanomaterials (LIMNO)	and electrochemical investigation of novel metal oxide-based photoanodes for visible light-driven hydrogen production	École polytechnique fédérale de Lausanne (EPFL), Switzerland	

FOREIGN LANGUAGES

Languages	level of knowledge
English	B2

AWARDS, ACKNOWLEDGEMENTS, SCHOLARSHIPS

Year	Description of award
2016	Post-Graduate Research Fellowship "Coherent 2D Electronic Spectroscopy methods development and application on supramolecular structures" Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Germany
2017	Post-Graduate Research Fellowship entitled "Borsa di studio per il proseguimento della formazione dei giovani più promettenti" within the SmartMatLab Project "Characterization and testing of smart materials", funded by Fondazione Cariplo and Regione Lombardia - Chemistry Department, University of Milan, Italy
2017	Scholarship funded by the Physical Chemistry Division of the Italian Chemical Society (SCI) to attend the XXVI National Congress of the Italian Chemical Society (SCI), Paestum, Italy, 10-14 September 2017
2017	Young Physico-Chemist Award 2017 for the Presentation "$TiO_2/BiVO_4$ Heterojunction for Photoelectrochemical Water Splitting" at the XXVI National Congress of the Italian Chemical Society (SCI), Paestum, Italy, 10-14 September 2017
2018	Scholarship funded by the Interdivisional EnerChem Group of the Italian Chemical Society (SCI), to attend the 1st Enerchem School, Firenze, Italy, 20-24 February 2018
2019	Scholarship funded by the Interdivisional EnerChem Group of the Italian Chemical Society (SCI), to attend the 2nd Enerchem Congress, Padova, Italy, 12-14 February 2020

TRAINING OR RESEARCH ACTIVITY

During my Master Thesis I had the chance to approach the field of 2D Electronic Spectroscopy, with the aim to reveal the quantum coherent mechanisms acting during ultrafast relaxation dynamics of molecular systems in the femtosecond time scale, possibly involved in the control of energy transfer processes both in natural and artificial photosynthetic systems. I focused my attention on BODIPYs dyes as model systems, a great example of biomimetic light-harvesters thanks to their structural analogy to the half-porphyrins, the artificial equivalent of chlorophylls. After my graduation, I continued working on 2D Electronic Spectroscopy for six months during a fellowship finalized to the development of new set up and methods to be applied in supramolecular structures.

With the achievement of a "borsa di studio per il proseguimento della formazione dei giovani più promettenti" funded by Fondazione Cariplo, in the group of Prof. Elena Selli at the University of Milan, I extended my research interests to metal oxide-based semiconductors development for solar energy conversion into clean fuels, and to photoelectrochemistry as fundamental class of characterization techniques, fruitfully collaborating with the SmartMatLab centre. Within the six months fellowship, I learnt how to prepare thin films of metal oxide materials, mostly optically transparent to allow their potential implementation in PEC tandem devices, by means of the easily processable spin coating technique followed by thermal treatment; particularly, I grasped how to manage the synthesis

parameters in strict relationship with the resulting photoelectrochemical (PEC) performance of the electrodes. In this way, I synthesized and investigated metal oxide materials both as such and in heterojunction systems, focusing my attention on the most studied WO_3, TiO_2 and $BiVO_4$ n-type semiconductors. I tested the performance of the prepared electrodes as photoanodes for solar water oxidation by means of a series of PEC techniques in a three-configuration cell, with the final goal to employ them in the overall water splitting reaction carried out, in combination with a cathode material, in a tandem cell. Among the different techniques employed, I devoted special attention to Linear Sweep Voltammetry (LSV) tests performed under standards conditions, *i.e.* AM 1.5 G solar simulated light (1 sun), allowing to check the photocurrent density generated by the material during a scan of increasing applied potential, and Incident Photon to Current Efficiency technique (IPCE), in order to evaluate the solar conversion efficiency of the electrode in terms of photocurrent recorded at each single wavelength, under a fixed applied potential. The stability of the electrodes was also checked by means of chronoamperometric (CA) analyses where the photocurrent produced at a fixed applied potential was monitored over prolonged time under 1 sun irradiation. Moreover, I also performed photocatalytic tests in a different set up without taking advantage of the external bias, to check the intrinsic photocatalytic reduction capability of the investigated materials towards methyl viologen, a well-known molecular probe whose reduction potential is close to that of water reduction, as effective method to evaluate the relative reducing power of a series electrodes in comparison.

During my three years PhD in Chemistry in the same research group, under the supervision of Dr. Maria Vittoria Dozzi, I dealt with a project concerning the development, through the synthesis parameterization and optimization, followed by the application of a series of characterization techniques, of several metal oxide-based photoanodes for solar water oxidation. Specifically, I focused on the implementation of three different families of materials, i.e. bismuth vanadate-, copper tungstate- and spinel ferrite-based semiconductor photoanodes. In the first two cases ($BiVO_4$ and $CuWO_4$), I investigated the doping with Mo as effective strategy to improve the charge transport properties of the film in addition to, in the specific case of $CuWO_4$, extending the visible light harvesting capability of the material through a narrowing of the bandgap energy. Moreover, the heterojunction of $BiVO_4$ with the wider bandgap TiO_2 oxide was studied with the aim to exploit the visible light capability of $BiVO_4$ and the superior reduction capability of the higher in energy TiO_2 conduction band, in the same photoanode system. Finally, $ZnFe_2O_4$ as prototype photoanode material of the spinel ferrites class was thoroughly investigated in collaboration with the group of Prof. Kevin Sivula at the EPFL of Lausanne, to understand the strict correlation occurring between crucial parameters such as the spinel structural disorder and the film crystallinity, both correlated to the annealing temperature, the film morphology, the thickness of the absorbing layer and the control of oxygen vacancies through a post-annealing hydrogen treatment, on the PEC performance, with the final goal to improve the remarkably poor charge separation of these materials. The investigated films were prepared via spin coating or chemical bath deposition to tune the film morphology from flat to nanostructured, respectively. A comprehensive characterization study of all prepared films was performed by means of structural (XRD, XPS, Raman), morphological (FESEM, AFM), optical (UV-Vis absorption), photocatalytic (molecular probes photoreduction) and PEC (LSV, CA, IPCE, cyclovoltammetry (CV) and Internal Quantum Efficiency (IQE)) techniques. Furthermore, I took advantage of the combination of electrochemical techniques such as Electrochemical Impedance Spectroscopy (EIS) and photo(electro)chromic experiments, with Transient Absorption Spectroscopy, to reveal the energetics of the investigated metal oxides and, in particular, the presence of intra bandgap states acting as recombination centers and/or intermediates for the water oxidation reaction, thus playing a pivotal role on the observed PEC performance. In particular, Transient Absorption Spectroscopy was also applied with the aim to monitor the charge carrier dynamics occurring in the picosecond time scale in both individual and composite photoanodes, which is a direct indication of the efficiency of photogenerated charge separation in the bulk of a semiconductor material.

During my visiting research period in the group of Prof. Sivula at the EPFL of Lausanne, where I worked on the engineering of $ZnFe_2O_4$ photoanodes by means of a thoroughly investigation of the crucial parameters affecting their PEC performance, I had the opportunity to acquire new skills in the photoelectrochemistry field, particularly in the acquisition, processing and interpretation of EIS data, as well as to approach the Intensity Modulated Photocurrent Spectroscopy (IMPS), a powerful frequency-domain electrochemical technique providing the unique advantage of clearly distinguishing the contributions from the bulk and the surface of the photoelectrode, working in operando conditions. Moreover, this internship period was a great opportunity to interface with an international community,

pioneering in the PEC field.

Overall, within my three PhD years I practised myself in the tutoring of Bachelor's and Master's students for their Thesis laboratory in the research group of Prof. E. Selli, as well as in the practicum laboratories scheduled during the Chemistry Bachelor's Degree course at the University of Milan.

PROJECT ACTIVITY

Year	Project
2014-2016	Title: "Novel photocatalytic materials based on heterojunctions for solar energy conversion" Project Code: 2013-0615 Funding Institution: Fondazione Cariplo - bando materiali avanzati 2013. Principal Investigator: Prof. Elena Selli, Università degli Studi di Milano (UniMi) Role: Participant.
2014-2016	Title: "Laboratorio multifunzionale e centro di formazione per la caratterizzazione e la sperimentazione preapplicativa di smart materials - SmartMatLab Centre" Project Code: 2013-1766 Principal Investigator: Prof. Elena Selli, Università degli Studi di Milano (UniMi) Funding Institution: Fondazione Cariplo and Regione Lombardia Role: Participant.
2017-2020	Title: "Solar driven chemistry: new materials for photo- and electro-catalysis (SMARTNESS)" Project Code: PROT20157FZLH. PRIN 2015 Funding Institution: Ministero dell'Istruzione, dell'Università e della Ricerca, MIUR. Principal local Investigator: Prof. Elena Selli, Università degli Studi di Milano (UniMi). Role: Participant
2019-2022	Title: "Multielectron transfer for the conversion of small molecules: an enabling technology for the chemical use of renewable energy (MULTI-e)" Project code Prot. 20179337R7, PRIN 2017. Funding Institution: Ministero dell'Istruzione, dell'Università e della Ricerca, MIUR. Principal local Investigator: Prof. Gian Luca Chiarello, Università degli Studi di Milano (UniMi) Role: Participant

CONGRESSES AND SEMINARS

Date	Title	Place
2017	XXVI National Congress of the Italian Chemical Society (SCI) Poster presentation entitled: "$TiO_2/BiVO_4$ Heterojunction for Photoelectrochemical Water Splitting" Authors: A. Polo, I. Grigioni, M. V. Dozzi and E. Selli	Paestum, Italy
2017	Italian Photochemistry Meeting (IPM) 2017 Oral presentation entitled: "$TiO_2/BiVO_4$ Heterojunction for Photoelectrochemical Water Splitting". Authors: A. Polo, I. Grigioni, M. V. Dozzi and E. Selli	Perugia, Italy
2018	1st EnerChem School of the Italian Chemical Society (SCI) Poster presentation entitled: "Molybdenum Doped $BiVO_4$ Photoanodes for Oxygen Evolution". Authors: A. Polo, I. Grigioni, M. V. Dozzi	Firenze, Italy

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	and E. Selli	
2018	10th European Meeting on Solar Chemistry and Photocatalysis: Environmental Applications (SPEA 10) Short oral and poster presentation entitled: "Photo(electro)catalytic characterization of Molybdenum Doped $BiVO_4$-based Photoanodes for Oxygen Evolution". Authors: A. Polo, I. Grigioni, M. V. Dozzi and E. Selli	Almeria, Spain
2019	UK-Italian joint meeting on Photochemistry 2019 Poster presentation entitled: "$CuW_{1-x}Mo_xO_4$ as efficient visible light harvester for photoelectrochemical water oxidation" Authors: A. Polo, C. Nomellini, I. Grigioni, M. V. Dozzi, E. Selli.	Lipari, Italy
2019	7th International Conference on Semiconductor Photochemistry (SP7) Short oral and poster presentation entitled: "Novel ternary metal oxide-based materials for extended visible-light photoactivity: the case of molybdenum doped copper tungstate" Authors: A. Polo, C. Nomellini, I. Grigioni, M. V. Dozzi, E. Selli.	Milan, Italy
2020	2nd Enerchem Congress funded by the Interdivisional EnerChem Group of the Italian Chemical Society (SCI) Oral presentation entitled: "Engineering of performance-boosting hydrogenation on $ZnFe_2O_4$ photoanodes: effects of thickness and thermal annealing temperature" Authors: A. Polo, F. A. Boudoire, C. R. J. Lhermitte, N. Guijarro, P. A. Schouwink, M. V. Dozzi, K. Sivula.	Padova, Italy

PUBLICATIONS

Articles
A. Polo, C. Nomellini, I. Grigioni, M. V. Dozzi, E. Selli, "Effective Visible Light Exploitation by Copper Molybdo-tungstate Photoanodes", ACS Appl. Energy Mater. 2020, 3, 6956–6964; doi:10.1021/acsaem.0c01021.
A. Polo, C. R. Lhermitte, M. V. Dozzi, E. Selli, K. Sivula, "Hydrogenation of $ZnFe_2O_4$ Flat Films: Effects of the Pre-Annealing Temperature on the Photoanodes Efficiency for Water Oxidation", Surfaces 2020, 3, 93-104; doi:10.3390/surfaces3010009.
C. R. Lhermitte, A. Polo, L. Yao, F. A. Boudoire, N. Guijarro, and K. Sivula, "Generalized Synthesis to Produce Transparent Thin Films of Ternary Metal Oxide Photoelectrodes", ChemSusChem 2020, 13, 3645 - 3653; doi:10.1002/cssc.202000926.
A. Polo, I. Grigioni, M. V. Dozzi, E. Selli, "Sensitizing effects of $BiVO_4$ and visible light induced production of highly reductive electrons in the $TiO_2/BiVO_4$ heterojunction", Catalysis Today 2020, 340, 19-25; doi:10.1016/j.cattod.2018.11.050.
L. Bolzonello, A. Polo, A. Volpato, E. Meneghin, M. Cordaro, M. Trapani, M. Fortino, A. Pedone, M. A.

Castriciano, E. Collini, "Two-Dimensional Electronic Spectroscopy Reveals Dynamics and Mechanisms of Solvent-Driven Inertial Relaxation in Polar BODIPY Dyes", J. Phys. Chem. Lett. 2018, 9, 1079-1085; doi:10.1021/acs.jpclett.7b03393.

OTHER INFORMATION

Member of the organizing committee of the International Conference on "Semiconductor Photochemistry (SP7)" held in Milan in September 2019
PhD representative of the Doctorate Course in Chemistry for the XXXIII cycle
Member of the organizing committee of the MeetMeOnChem event at the Chemistry Department of the University of Milan
Member of the "Italian Chemical Society (SCI)" since 2017
Member of the "Gruppo Italiano di Fotochimica (GIF)" since 2019
Tutoring to Chemistry Bachelor's students in the Physical Chemistry 2 Laboratory held by Prof. Alberto Vertova (439/M-tutorato), according to the "Incarico di collaborazione finalizzata al tutorato e ad attività integrative della didattica ai sensi dell'art. 45 Regolamento Generale d'Ateneo" - Chemistry Department - University of Milan - Codice ID: 439/M (2018)
Tutoring to Chemistry Bachelor's students in the Physical Chemistry 2 Laboratory held by Dr. Mariangela Longhi and Dr. Maria Vittoria (668/O -tutorato), according to the "Incarico di collaborazione finalizzata al tutorato e ad attività integrative della didattica ai sensi dell'art. 45 Regolamento Generale d'Ateneo" - Chemistry Department - University of Milan - Codice ID: 668/O (2019)
Tutoring to Industrial Chemistry Bachelor's students in the Physical Chemistry - B - Laboratory held by Prof. Gian Luca Chiarello (765/B-tutorato), according to the "Incarico di collaborazione finalizzata al tutorato e ad attività integrative della didattica ai sensi dell'art. 45 Regolamento Generale d'Ateneo" - Chemistry Department - University of Milan - Codice ID: 765/B (2020)

Declarations given in the present curriculum must be considered released according to art. 46 and 47 of DPR n. 445/2000.

The present curriculum does not contain confidential and legal information according to art. 4, paragraph 1, points d) and e) of D.Lgs. 30.06.2003 n. 196.

Place and date: Milano, 11/11/2020

SIGNATURE

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