Project summary

Applicant

Last Name	First Name	Tax Identification Number	Gender
CASALBONI	MAURO	CSLMRA54C02D773E	M

Department/Centre
Dipartimento di Ingegneria industriale

Position
Docenti di ruolo di Ia fascia

E-mail	Telephone	Fax
casalboni@uniroma2.it	4522	

Project

Acronym

SRRS

Research Programme Title

Slot Ring Resonator for biochemical Sensor

Interdisciplinarity

Yes

Submitted

July 1, 2019 12:34

Main Erc

PE Physical Sciences and Engineering \PE4 Physical and analytical chemical sciences \PE4_8 Electrochemistry, electrodialysis, microfluidics, sensors (60%)

Secondary Erc

LS Life Sciences \LS7 Diagnostic tools, therapies and public health \LS7_2 Diagnostic tools (e.g. genetic, imaging) (40%)

Main CUN Area

02 - Scienze fisiche (60%)

Secodary CUN Area

03 - Scienze chimiche (40%)

Main Scientific Disciplinary Sector

FIS/03 - FISICA DELLA MATERIA (60%)

Secondary Scientific Disciplinary Sector

CHIM/03 - CHIMICA GENERALE E INORGANICA (40%)

Number of Partecipants

3

Number of external Partecipants

2

File Attachments

1

Total Costs

€20000

Project Plan

Year	Language	Acronym
2019	en	*SRRS*

Research Programme Title

Slot Ring Resonator for biochemical Sensor

Abstract of the Research Programme

This project proposes a hybrid-waveguide ring resonator for on-chip biochemical sensing consisting of a low-loss strip-waveguide and a highly sensitive slot-waveguide integrated in a silicon photonic platform. It is demonstrated that the hybrid-waveguide concept may overcome limitations in terms of overall resonator sensitivity.
Such a device provides the unique feature to increase the sensitivity while maintaining low optical losses. The resulting structure represents a promising approach for integrated biochemical sensing applications. The effectiveness of the proposed device is suggested by a theoretical analysis, involving numerical simulation of the hybrid-waveguide ring resonator and an optimization of the slot-waveguide structure with regard to light –analyte interaction developed in previous studies implemented in a international cooperation. Thanks to the participation of our colleagues that will provide the basic device, we will functionalize it in order to make it sensitive at ROS (Reactive Oxygen Species) produced in oxidative stress condition that are known to contribute to several diseases, including cardiovascular diseases, neurodegenerative diseases, chronic obstructive pulmonary disease, atherosclerosis, hypertension, diabetes, acute respiratory distress syndrome, chronic kidney disease, and cancer.

State of the Art

Biochemical sensors based on integrated optical ring resonators have gained increasing interests over the last decade [1], [2]. They can lead to major advances in biochemical sensing through the rapid and precise analysis offering the prospect of an inexpensive lab-on-a-chip platform and a reliable point-of-care diagnostic for the detection of proteins in food, toxins in the environment or blood analysis [3]. Especially silicon photonic sensors have become very attractive for various optical sensing applications. Using silicon-on-insulator as a material platform provides the ability to fabricate photonic sensors with electronic circuits on a single chip (monolithic integration) [4]. Silicon photonics is compatibile with CMOS processes making this technology attractive from the commercial point of view.
Silicon photonic circuits are based on low loss strip-waveguides where only the evanescent field interacts with the analyte (20% of the overall light intensity) due to the strong field confinement inside the high index silicon waveguide [5]. In contrast, vertical slot waveguides provide much higher light-analyte-interaction at the cost of increased optical losses [6]–[8]. As consequence, slot-waveguide ring resonator sensors [9] have been proved to increase the ring resonator sensitivity by a factor of about four compared to strip-waveguide ring resonator sensors [10]. So far, this has not yet been translated into a corresponding increase of detection limit [9]. Major drawback of the slot-waveguide is the relatively high optical losses[11], [12]. In order to find an optimal trade-off between low optical losses and high sensitivity we propose a strategy using the best performing technologies of strip- and slot-waveguides
in different sectors of the device. Finally various signal enhancement strategies have been developed to increase sensitivity, for example nanoparticle greatly enhances the optical field strength enabling the discrimination of single-molecule binding events [13,14]. Moreover, the proper functionalization of nanoparticles surface ensure specific binding events and then selective sensor responses within complex media.

[1] C. Ciminelli, et al Progr. Quantum Electron. 37, 51, 2013
[2] A. F. Gavela, et al Sensors, 16, 285, 2016
[3] V. M. N. Passaro, et al Sensors,12, 15558, 2012.
[4] T. Taniguchi, et al Jpn. J. Appl. Phys. 55, 04EM04, 2016
[5] P. Steglich, et al Proc. 3rd Int. Conf. Photon., Opt. Laser Technol., 2015, p 47
[6] V. R. Almeida, et al Opt. Lett., 29, 1209, 2004
[7] C. A. Barrios et al, Opt. Lett. 32, 3080, 2007
[8] T. Taniguchi et al Opt.Commun. 365, 16, 2016
[9] T. Claes, et al IEEE Photon. J., 1, 197, 2009.
[10] K. De Vos, et al Opt. Exp. 15, 7610, 2007.
[11] R. Ding et al,Opt. Exp. 18, 25061, 2010
[12] T. Alasaarela et al, Opt. Exp.19, 11529, 2011
[13] MD Baaske et al Nat Nanot. 9, 933 2014
[14] HW James et al Rev Anal Chem 9, 1, 2016

Research Programme Description

Research Programme description (100-5000)
A hybrid-waveguide ring resonator sensor is proposed for the fabrication of the device, goal of the present project. It combines a high sensitive slot-waveguide with a low loss and strongly guiding strip waveguide in a single ring. The innovative aspect we present in this paper is twofold. First, we propose the hybrid-waveguide ring resonator concept as photonic sensor for optical sensing and present an approach to optimize this ring resonator for homogeneous sensing. Second, we provide a proof of concept of homogeneous sensing with the optimized ring structure and show an increased overall sensitivity compared to most traditional slot- and strip-waveguide ring resonators. The overall sensitivity is quantified by a figure of merit that takes into account the optical losses and the ring resonator sensitivity.
The project is aimed to functionalize the hybrid ring resonator by means of functionalized nanodiamonds embedded in porous polymer matrix. The use of nanodiamond, a material with high refractive index, could improve sensitivity of the sensor and are the perfect platform for chemical functionalization. Nanodiamond will be functionalized using some enzyme sensitive to ROS such as superoxide dismutase (SOD), catalase (CAT) and Glutathione peroxidase (GPx) in order to sensitize the device to ROS.

The plan of the project consists in five major phases:

1.Preliminary studies devoted on the functionalization of nanodiamond and nanocomposite preparation and characterization will be performed (months 1-6).
2.Measurement ex-situ of enzymatic activity of nanocomposite materials by standard ROS solutions (month 1-6)
3.Using the hybrid ring resonators provided by our colleagues from THW (Technische Hochschule Wildau) and IHP (Innovations for High Performance Microelectronics – Frankfurt Oder – Germany) that were an excellent result of previous common cooperative research we will prepare the set-up for reliable and accurate measure of the frequency resonance of the non sensitized ring resonator. (months 1-6)
4.Implementation of active ring resonator will be obtained with spinning procedure in our clean room. The optimization of the spinning procedure for nanocomposite materials has to be carefully accomplished in order to define a reliable and reproducible way for active device fabrication. (months 7-10)
5.Measurements aimed to characterize the effectiveness of the detection strategy will be performed in ore laboratory of guided optics, with the participation of INFN researchers (dr Andrea Salamon). During this phase an optimization of the spinning procedure will take a consistent amount of time. The measurements of the detection limit for ROS will be performed using different concentration of analyte. (months 11-18)

Objectives and Expected Results of the Research Programme

Objective of the project is the validation of a hybrid-waveguide ring resonator consisting of
standard silicon slot- and strip-waveguide as a possible device for detection of ROS. The term ‘reactive oxygen species’ , ROS, is applied to both free radicals and their non-radical intermediates and could have endogenous or exogenous origin. ROS over-production leads to oxidative stress that is recognized to play a central role in the pathophysiology of many different disorders, including complications of pregnancy.
It is now well known that oxidative stress is a response of the organism to environmental pollution. Moreover, exogenous ROS in air pollution play an important role in many health effects involving oxidative stress and lead to damage of lipids, proteins, and macro-molecules such as DNA and RNA and inflammation.
ROS can be also over generated by organisms exposed to toxic substances both in aquatic and terrestrial environmental and could be used as indirect indicator of the quality of water and soil.
However, reactive species present some characteristics that make them difficult to detect, namely their very short lifetime and the variety of antioxidants molecules capable of capturing these reactive species. Finally, many of the developed sensors work only in a specific concentration range (micro-molar concentration) and exhibit several difficulties in selectively detecting ROS when they are mixed with other materials.
It is, therefore, essential to develop methodologies capable of overcoming this type of obstacles and optical sensors seems to be the more promising in this field.
Objective of the project is to develop a hybrid sensor that seeks to combine the benefits of optical sensors in term of sensitivity, response time, resolution with the selectivity of a biosensor and that could be directly applied in the environmental analysis.
The proposed biosensor should provide advantages compared to existing silicon slot- and strip-waveguide ring resonators in terms of high overall sensitivity described by the FOM. Besides a proof of principle of this strategy, we consider as objective the determination of the detection limit for ROS for this specific kind of integrated detector.
It is a further important goal the assessment of a reproducible procedure and a quantitative
determination of the reliability of the device.
This achievements would demonstrate that hybrid-waveguide ring resonator is an actual alternative
approach to standard strip- and slot-waveguide ring resonators for sensing applications with a
large range of measurements.

Department/Centre

Please select 2 or more characters to search Department/Centre

Key words

sensors,biosensors,optical,optical resonators

PI and Research Group (3)

(1/3) CASALBONI MAURO Principal Investigator

Gender

M

Tax Identification Number

CSLMRA54C02D773E

Position

Docenti di ruolo di Ia fascia

Agency

Università degli Studi di Roma Tor Vergata

Department/Centre

Dipartimento di Ingegneria industriale

Actual Position

PO - Professori Ordinari

Accademic Seniority

1978

Contacts

E-mail	Telephone	Fax
casalboni@uniroma2.it	4522	

Scientific Informations

Main Scientific Disciplinary Sector

FIS/03

Scientific Curriculum Vitae

Born in 1954, Degree in Physics (1978)
1978 – 1981 Italian central health institute (Istituto Superiore di Sanità)
1981 – 1982 Department of Physics of the University of Rome “La Sapienza”
1984 – 1992 University Researcher at the Physics Department of the University of Rome - Tor Vergata.
1992 – 2004 Associate Professor at the University of Camerino and Rome - Tor Vergata
2004 now Full Professor (FIS03 – 02/B1) at the Department of Industrial Engineering of the University of Rome - Tor Vergata, Rome
He teaches since a.a. 1981 / '82 many courses from basic Physics to Solid Stae Physics.
He was active as proposer and coordinator of a number of international activity (international doctorate, german-italian double degree, joint Phd and Master thesis)
He has been a Degree thesis supervisor (about 70) and Ph.D. thesis supervisor (more than 25).
He is active in dissemination of scientific knowledge and schoolteacher’s training since 1995
His scientific activity has begun on Jahn-Teller impurities in alkaline halides, ionic impurities, Cr and color centers in insulators.
He was committed in the first experiment of two-photon absorption of pure Alkali Halides using Synchrotron Radiation.
He dealt with the synthesis and optical characterization of glassy materials produced with sol-gel technique, in particular on the interaction of ions and molecular dyes with the matrix. Noticeable was the study of electro-optical molecules in organic / inorganic hybrid films obtained by sol-gel process.
More recently he studied Nanocomposite materials, self-aggregated systems, photonic crystals, quantum dots, guided optics and related devices.
In this context very recently a particular attention was devoted to ring resonators used as optical modulators. This topic, stemming from previous study of E-O devices and thanks to the cooperation with Technische Hochshule Wildau and IHP Frankfurt (Oder), has led to the development of high performance ring resonator proposed as modulators and biosensor.
He is the author of about 140 and is co-author of three industrial patents
he coordinated many national and international projects (1996 CNR, 1998-2001 Prin (275.000 €),
2000 PRIN (153.000 €), 2001 he participate to a FIRB (60.000 €), 2002 local point for a prin (72.500 €)
2003 partecipate to a FIRB (125.000 euro) 2004 local PRIN coordinator.
2004 – 2008 He is the European coordinator of a STREP project (ODEON) in which 11 operative units participant from 7 european and extraeuropean partners. This project dealt with innovative electrooptical modulators based on organic / inorganic hybrid materials. The total budget was 3.78 M€ The project was mentioned as a success case of the FP6 in the EU commission

brochure (doi 10.2777/96506);2005 - 2007 local coordinator of (STREP FP6) INDIGO (129.000 €); 2011 - 2013 Local coordinator of a CARIPLO project (141.000 €)

Scientific Pubblications

- [2017][Articolo su rivista] Steglich, P., Villringer, C., Pulwer, S., Heinrich, F., Bauer, J., Dietzel, B., et al. (2017). Hybrid-Waveguide Ring Resonator for Biochemical Sensing. IEEE SENSORS JOURNAL, 17(15), 4781-4790.
- [2015][Articolo su rivista] Steglich, P., Mai, C., Stolarek, D., Lischke, S., Kupijai, S., Villringer, C., et al. (2015). Novel Ring Resonator Combining Strong Field Confinement with High Optical Quality Factor. IEEE PHOTONICS TECHNOLOGY LETTERS, 27(20), 2197-2200.
- [2018][Articolo su rivista] Alimonti, G., Ammendola, R., Andreazza, A., Badoni, D., Bonaiuto, V., Casalboni, M., et al. (2018). Use of silicon photonics wavelength multiplexing techniques for fast parallel readout in high energy physics. NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH. SECTION A, ACCELERATORS, SPECTROMETERS, DETECTORS AND ASSOCIATED EQUIPMENT.

(2/3) FRANCINI ROBERTO Partecipant

Gender

M

Tax Identification Number

FRNRRT55R24G702D

Position

Docenti di ruolo di IIa fascia

Agency

Università degli Studi di Roma Tor Vergata

Department/Centre

Dipartimento di Ingegneria industriale

Actual Position

PA - Professori Associati

Accademic Seniority

1981

Contacts

E-mail	Telephone	Fax
francini@roma2.infn.it	4505	

Scientific Informations

Main Scientific Disciplinary Sector

FIS/03

Scientific Curriculum Vitae

Since 2001 Associate Professor (SD FIS/03, Solid State Physics) at the Department of Industrial Engineering, University of Rome Tor Vergata
1984 – 2001 Researcher at the Department of Physics, University of Rome Tor Vergata
1975 – 1981 Physics Degree from the University of Rome La Sapienza, December 12, 1980, obtained with the maximum grade 110/110 cum laude, discussing the experimental thesis “Two-photon Spectroscopy in Siver Chloride” under the supervision of Prof. U.M. Grassano
Affiliations:
Researcher of The National Group of Solid State Physics, in the Unit “Semiconductors and Optical Properties of Solids” of the Institute of Physics “G. Marconi”, Rome, and later in the Unit “Electronic and Magnetic Properties of Solids” of the Physics Department of the University of Rome Tor Vergata.
Researcher of CNISM (ex INFM) at the Unit of Tor Vergata, Rome.
1981 Abroad study grant CNR.
1982 Study grant Della Riccia Foundation.
1982 Entitled of an abroad study grant CNR.
Schools
1981 National School of Solid State Physics of the CNR, held in Lecce, Italy.
1994 International Workshop “"Non-linear electromagnetic interactions
in Semiconductors" held in Trieste, Italy.
1981 – 1982 Research activity in Non-linear Spectroscopy in the Laser Spectroscopy Laboratory of Prof. D. Frohlich, University of Dortmund, Germany.
Visiting researcher at the Institute of Physics, Jagellonian University Krakow, Poland for short periods in 1989, 1990, 1991 e 1997.
Academic appointments
Representative of researchers at the Faculty of Science , Uni. Tor Vergata

Member of the “giunta del Dipartimento” at the Physics Dept. Uni. Tor Vergata
Local coordinator for Materials Science of the national didactic project “Scientific Degree Project” of the Italian Ministry of Education
2008 – 2014 President of the bachelor degree in Materials Science and the Master degree in Materials Science and Technology, Uni. Tor Vergata
2008 – 2014 Erasmus Reference scientist for the bachelor degree in Materials Science and the Master degree in Materials Science and Technology, Uni. Tor Vergata
Teaching experience:
Laboratory of physics, General Physics for the bachelor degrees in Physics, Materials Science and Medical Engineering.
Supervision of about 15 master degree students
Research experience:
two-photon spectroscopy, non-linear and laser spectroscopy, solid state physics, impurities and defects, insulating materials, optical properties, photoluminescence, rare-earth ions, vacuum UV, infrared, absorption and excitation spectra, nanomaterials, Jahn-Teller systems, Color centers, glasses, scintillators.
Local coordinator of national projects, CNR and PRIN
Scientific coordinator of study and research student grants.
Referee of international journals: JINST, J. Lumin, JSSC, J. App. Phys., J. of Phys, Cond. Matt., Eur. J. Of Inorg. Chem, Materials Lett., Opt. Mat.
Author of more than 70 papers on international journals.

Scientific Pubblications

- P. Castrucci, F. Fabbri, T. Delise, M. Scarselli, M. Salvato, S. Pascale, R. Francini, I. Berbezier, C. Lechner, F. Jardali, H. Vach, M. De Crescenzi
  Raman investigation of air-stable silicene nanosheets on an inert graphite surface
  Nano Research 11(11) 5879 – 5889 (2018).
  https://doi.org/10.1007/s12274-018-2097-6
- L. Burratti, F. De Matteis, M. Casalboni, R. Francini, R. Pizzoferrato, P. Prosposito
  Polystyrene photonic crystals as optical sensors for volatile organic compounds
  Materials Chemistry and Physics 212, 274 – 281 (2018)
  https://doi.org/10.1016/j.matchemphys.2018.03.039
- C. Rogge, S. Zinn, P. Prosposito, R. Francini, A. H. Foitzik
  Transmitted Light pH Optode for Small Sample Volumes
  Journal of Sensors and Sensor Systems 6, 351-359 (2017), https://doi.org/10.5194/jsss-6-351-2017, 2017

(3/3) ORLANDUCCI SILVIA Partecipant

Gender	Tax Identification Number	Position
F	RLNSLV74B45H501K	Docenti di ruolo di IIa fascia

Agency	Department/Centre
Università degli Studi di Roma Tor Vergata	Dipartimento di Scienze e Tecnologie Chimiche

Actual Position	Accademic Seniority
PA - Professori Associati	2004

Contacts

E-mail	Telephone	Fax
silvia.orlanducci@uniroma2.it	4402	4328

Scientific Informations

Main Scientific Disciplinary Sector

CHIM/03

Scientific Curriculum Vitae

Silvia Orlanducci, born in 1974, graduated in Chemistry at the University of Rome "La Sapienza" with marks 110/110 in 2000. In 2000 she was awarded a scholarship to fund the doctoral studies at the University of Rome "Tor Vergata" in collaboration with the INFN_LNF and in 2004 she was awarded the Ph.D. in Chemistry with the doctoral thesis "Synthesis and characterisation of nanostructured carbon materials".
From 2004 to 2007 she was post-doc associate researcher. In 2005 she was awarded a fellowship for the research: "Cathodoluminescence analysis of diamond films and carbon nanotubes coated by a nanodiamond " at Research Institute of Nanoscience (RIN), KIT, Kyoto Japan. In 2007 she awarded a position of Researcher (CHIM03) at the Faculty of Science of Tor Vergata University. In 2014 she awarded a position of Associated Professor (CHIM03) at the Dept. of Chemical Science and Technology at Tor Vergata University of Rome. In 2013 she won the medal R. Nasini conferred by the division of Inorganic Chemistry of the SCI.
Her research activity mainly performed in the frame of Inorganic Chemistry and Material Chemistry, and focused to the settling of synthesis methodologies, treatments and structural/functional characterizations of nanomaterials. The main research line deals with the carbon-based nanomaterials: nanodiamonds, nanotubes, nanographites, the chemical fuctionalization and the coupling of these nanomaterials each other or to metal and metal oxide nanoparticles.
She is co-author of more than 140 papers published in peer-reviewed journals, 1 book chapters, 4 review, 2 edited book, 2 patents, and 46 proceedings “peer reviewed”, she has been invited as speaker at International Conferences. She received more than 2500 citation, up to now her H index is 23.

Lab activities and facilities
The unit has the scientific expertise as well as the skills and the facilities for the synthesis of the materials and their structural characterizations. The experimental facilities available for the present project include a Hot Filament Chemical Vapor Deposition (HFCVD) and a Plasma Enhanced Chemical Vapor Deposition (PECVD) for the synthesis and plasma treatment of carbon nanomaterials. The activity of synthesis and post-synthesis treatment of nanomaterials were supplemented by several characterization techniques in which acquired considerable expertise: scanning electron microscopy (SEM), spectroscopic techniques (Raman, photoluminescence), electron diffraction RHEED, X-rays diffraction, atomic force and scanning tunneling microscopy (AFM, STM), UV-Vis spectroscopy, controlled potential electrochemical techniques.

Scientific Pubblications

- Orlanducci, S. Gold-Decorated Nanodiamonds: Powerful Multifunctional Materials for Sensing, Imaging, Diagnostics, and Therapy, (2018) European Journal of Inorganic Chemistry, 2018 (48), pp. 5138-5145.

- Reina, G., Peruzzi, C., Orlanducci, S., Terranova, M.L. “Recovery of Co from aqueous solutions using nanodiamonds as solid adsorbents” (2017) Physica Status Solidi (A) Applications and Materials Science, 214 (1), art. no. 1600477,
- Orlanducci, S., Cairone, C., Tamburri, E., Lenti, S., Cianchetta, I., Rossi, M., Terranova, M.L. “Rhodamine/nanodiamond as a system model for drug carrier” (2015) Journal of Nanoscience and Nanotechnology, 15 (2), pp. 1022-1029.
- Gismondi, A., Reina, G., Orlanducci, S., Mizzoni, F., Gay, S., Terranova, M.L., Canini, A. “ Nanodiamonds coupled with plant bioactive metabolites: A nanotech approach for cancer therapy” (2015) Biomaterials, 38, pp. 22-35.
- Tamburri, E., Guglielmotti, V., Orlanducci, S., Terranova, M.L., Sordi, D., Passeri, D., Matassa, R., Rossi, M. “Nanodiamond-mediated crystallization in fibers of PANI nanocomposites produced by template-free polymerization: Conductive and thermal properties of the fibrillar networks” (2012) Polymer, 53 (19), pp. 4045-4053. Cited 29 times.

External Participants (2)

N.	Last Name	First Name	Agency	Position	Foreign Agency/ Partecipant	In case of collaboration with foreign research entities (public, private,non-profit, including universities and research organizations), or withforeign researchers, the PI declares that this collaboration is completelyin line with the program, the topics and with the scope of the project
1	Salamon	Andrea	infn	Ricercatore		
2	Steglich	Patrick	IHP (Frankfurt O.)	ricercatore	1	1

ERC

Main Erc

PE Physical Sciences and Engineering \PE4 Physical and analytical chemical sciences \PE4_8 Electrochemistry, electrodialysis, microfluidics, sensors (60%)

Secondary Erc

LS Life Sciences \LS7 Diagnostic tools, therapies and public health \LS7_2 Diagnostic tools (e.g. genetic, imaging) (40%)

CUN Areas and SSD

Main CUN Area

02 - Scienze fisiche (60%)

Secodary CUN Area

03 - Scienze chimiche (40%)

Main Scientific Disciplinary Sector

FIS/03 - FISICA DELLA MATERIA (60%)

Secondary Scientific Disciplinary Sector

CHIM/03 - CHIMICA GENERALE E INORGANICA (40%)

Programme Cost

Equipment/books	
computer and small equipments for laboratory	€ 4000
Consumables	
plastic ware, glass ware, chemicals, reagents, fiber optics, optical mounts; equipment maintenance.	€ 7000
Costs for facilities not owned by the University and/or publication expenses (up to 50% of the total project cost)	
dissemination and publication cost, possible spin off cost	€ 3000
Travel expenses	
travel and mission to IHP a Frankfurt Oder or to the lab of Technische Hochschule Wildau (Berlin)	€ 3500
Overheads (up to 20% of the total project cost)	
Management and coordination costs	€ 2500
Scholarships / coordinated and continuous collaboration contracts	
no scholarships will be appointed	€ 0
Total Cost	
	€ 20000

File Attachments

N.	File Name	Description
1	figures.pdf	ring resonator schematics and operation principle

Applicant's Signature

The Applicant
MAURO CASALBONI