Khouloud ABID | Curriculum Vitae

Adress: [redacted]

Nationality: [redacted] Date of Birth: [redacted]

(+39) [redacted]

[redacted]

Affiliations:

Department of Engineering, University of Messina, I-98166 Messina, Italy
NR IPCF Istituto per i Processi Chimico-Fisici, viale F. Stagno D'Alcontres 37, I-98156 Messina, Italy

Scientific Background

I am a researcher in physics and chemistry. I am interested in synthesis of two-dimensional (2D) materials, plasmonic nanoparticles and their hybrid/nanocomposites. I am interested to study the features of the these materials and their performance in the sensing field especially, plasmonic, electrochemical, optical and fluorescent. I am able to work with Raman, PL, UV-Vis, FTIR and AFM techniques. I am open also to learn new skills.

EDUCATION

Diploma of doctorate in 'Engineering and Chemistry of Materials and Constructions' and Diploma of doctorate in Condensed physics specialized in nanomaterials. **19/12/2019- 12/12/2022**

Department of Engineering, University of Messina-Italy and Department of Physics, University of Sfax-Tunisia
My thesis was under the joint supervision of University of Sfax-Tunisia and University of Messina-Italy (2019-2022) in collaboration with Istituto per i Processi Chimico-Fisici (IPCF, CNR). In fact, I worked with two type of sensors; the plasmonic sensors similar to my master work, and the electrochemical sensors. During these three years, my research focuses on nanomaterials since they have gained outstanding interest worldwide, especially on transition metal dichalcogenides "TMDCs" (MX2; MoS2, WS2, MoSe2..). The aim is to exfoliate a low number of layers of MX2 with a low-cost technique for the detection at low traces purpose. This investigation began in my master dissertation work in 2019 where we have exfoliated MoS2 and WS2 nanosheets using a top-down technique known as liquid-phase exfoliation (LPE) followed by liquid cascade centrifugation (LCC). These nanosheets (NS) were characterized using scanning electron microscope (SEM), atomic force microscopy (AFM), photoluminescence (PL) in addition to Raman and ultra-violet visible (UV-Vis) spectroscopies and we have computed various parameters based on these data (number of layers, concentration, length, bandgap energy). These nanosheets are used later to develop electrochemical and plasmonic sensors either pure or nanocomposite forms. For the plasmonic sensing goal, we have coated these nanosheets with gold nanoparticles in order to improve their features to create enhanced Raman scattering (ERS) substrates. Two tools were used for the determination of specific analyte used as probe molecules, surface-enhanced Raman scattering (SERS), and photo-induced enhanced Raman scattering (PIERS). Their high sensitivity in detecting small traces unlike the Raman technique has motivated us to use it in the sensing field in addition to their crucial enhancement in the Raman signals owing to the charge transfer (CT) mechanism that may be checked based on the semiconductor theory. For the electrochemical sensing goal, the nanosheets were used as pure or hybrid form to determine several analytes like bio-molecules (folic acid,

dopamine) and pesticides (Thiram). For the prior probe molecules, graphene oxide (GO) to create GO@WS2 nanocomposite that shows fascinating findings for the determination of Thiram fungicide at low concentrations. Moreover, two different shapes of 2D-gold were used ; gold nanoparticles (AuNPs) and gold nanorods (AuNRds). The first type were used to prepare AuNps@MoS2 using the electrodeposition method for the development of dual plasmonic and electrochemical sensor Folic acid (FA) and we found a different a new sensing mechanism using this platform. The second type is used to form AuNrds-MX2 and was tested for the determination of dye molecule which is methylene blue (MB). Moreover, AuNPs were synthesized using green synthesis path and the average size of these nanoparticles was 50nm with average spherical shape that were used later to create AuNps@MoSe2 nanocomposite. These platform shows fascinating performance toward the determination of neurotransmitter molecule.

- Title: "Development of Two-Dimensional (2D) Sensing Materials ".
- Supervisor: Prof. Giovanni Neri and Prof.Ramzi Maalej/ Co-Superviser: Prof. Pietro Gucciardi and Dr. Antonino Foti
- Competence: PIERS, SERS, synthesis plasmonic nanoparticles, synthesis 2D materials, sensing, electroanalytical technique, Raman, PL, UV, FTIR, AFM, synthesis of 2D nanocomposites
- Final decision: very good with written jury congratulations (in Tunisia)/ lode (in Italy)
- Delivered date: January 2023.
- Diplom are delivered from Faculty of sciences of Sfax-University of Sfax-Tunisia and University of Messina-Italy

Master in Physics **15/09/2017 - 06/12/2019**

Dipartment of Physics, University of Sfax-Tunisia

My master's work is a tri collaboration between Tunisia, Italy, and Saudi Arabia under the supervision of Mr.Ramzi Maâlej and the co-supervision of Mrs. Nour HAmza Belkhir. The aim of this work is the development of two-dimensional (2D) sensing materials. Here, we have been interested in the transition metal dichalcogenides (TMDCs) family, where we have chosen the tungsten disulfide (WS2) due to its fascinating properties. The WS2 nanosheets (NS) were exfoliated using the ultrasonic method known also as the liquid phase exfoliation (LPE) technique, then, coated with gold nanoparticles (AuNPs) that were synthesized using the Turkevish-Frens procedure. The pure WS2, AuNPs, and hybrid Au@WS2 were characterized by several techniques. To study the optical and structural of WS2 NPs, we have used Raman and UV-Vis spectroscopy. Based on Raman data, the WS2 NS number of layers was determined. Using UV-Vis findings, the concentration, length, and number of layers of the nanosheets were determined. For AuNPs, the UV-Vis spectroscopy was employed to determine the localized Surface Plasmon Resonant (LSPR) was determined. The hybrid Au@WS2 was used as SERS/PIERS substrates to detect 4-mercaptobenzoic acid (MBA) at low traces. Later, SERS and PIERS techniques were employed to check the efficiency of our substrates. The obtained data figure out significant findings, where the Raman signals were strongly enhanced for both SERS and PIERS substrates. Indeed, the use of PIERS substrate has shown the most important Raman signals enhancement (4 times than that of SERS). The fruit of this outstanding work is published in 2020 in the Journal of Physical Chemistry C.

- Title: "PIERS and SERS Performance of MX2-Au Nanomaterials for MBA Detection".
- Supervisor: Prof.Ramzi Maalej/ Co-Superviser: Prof.Nour Hamza Blekhir
- Competence: PIERS, SERS, plasmonic nanoparticles, 2D materials, sensing
- Final decision: 18.5/20 (for the mster defense with honors). 13.5/20 (for the two years of the master)

- Data di conseguimento: December 2019.
- Diplom is delivered from Faculty of sciences of Sfax-Univeristy of Sfax-Tunisia

Diploma of Bachelor of Physics and Chemistry **2014-2017**

Faculty of Sciences of Sfax-Tunisia

- Principle courses: Chemistry, physics, informatics, English and French languages
- Rank the 4th .

Diploma of Baccalaureat (Mathematic) **2014**

High School Maazoun, Sfax

- Final decision: 12.23/ 20; Near good
- Date: 21/06/2014
- Diploma delivered from Ministry of education of Tunisia

PARTICIPANTS IN SCHOOLS

- e-spark Summer school in electrochemistry

Date: 18-24 September 2022. **Location:** Warsaw-Poland

- The International School on Programmable Smart Sensors based on Bio-compatible Nanocomposite Materials (NanoSENS)- Online

Date: 17-24 June 2021

RESEARCH ACTIVITIES

Assegno di ricerca Post Doc **01/01/2023 – present**

Department of Engineering, University of Messina-Italy

I am working as postdoctoral in LabSens Porf.Neri group and in collaboration with Consiglio Nazionale delle Ricerche (CNR) in Messina, Italy. During this period, an electrochemical sensor based on MoS2 nanosheets is developed for the determination of heavy metal ions in seawater at low concentrations. An florescent and optical sensors are developed also to determine these ions and rare earth ions using MX2 nanosheets and MX2-based nanocomposites. In parallel with this work, a sensor is developed based on TiO2-MoSe2 nanocomposite prepared through solvothermal technique where its efficiency is checked with drug molecule.

During this period, I supervised three students and I submitted until now three papers as first author and two as second author. From this supervision, a paper about dopamine (DA) determination is published "A Sensitive and Selective Non-Enzymatic Dopamine Sensor Based on Nanostructured Co3O4–Fe2O3 Heterojunctions" in chemosensors journal.

PROJECTS PARTICIPATION

- Title of project: TEcnologie innovative per il controllo, il moniToraggio e la sIcurezza in mare (TETI)

Role: Development of electrochemical sensors for the determination of contaminants in seawater
Period: From 01/01/2023 to 31/12/2023.

Title of project: SAMOTHRACE

Role: Development and characterization of a plasmonic sensor based on nanomaterials made of two-dimensional transition metal dichalcogenides in combination with noble metal nanoparticles for the detection of pollutants and toxins at low concentrations for applications of environmental interest.
Period: From 01/01/2023 to 30/06/2023.

PUBBLICATIONS

October 2023: '' A study of Screen-Printed Electrodes Modified with MoSe2 and AuNPs-MoSe2 Nanosheets for Dopamine Sensing''
Abid, K.; Foti, A.; Khaskhoussi, A.; Celesti, C.; D'Andrea, C.; Polykretis, P.; Matteini, P.; Iannazzo, D.; Maalej, R.; Gucciardi, P. G.; Neri, G.
Electrochimica Acta **2023**, 143371.DOI : **10.1016/j.electacta.2023.143371**

Abstract: '' Molybdenum selenide nanosheets (MoSe2-NS) were synthesized by liquid-phase exfoliation (LPE) technique and successive liquid cascade centrifugation (LCC) at two different centrifugation rates (1.5 and 5 krpm). By this technique's combination, we were able to prepare MoSe2 nanosheets with different geometric characteristics (i.e., average number of layers <N> and average lateral length <L>). Increasing the centrifugation speed from 1.5 krpm to 5 krpm leads to a decrease in number of layers (down to nL = 2 – 4, with the presence of sparse monolayer flakes) and average lateral size of NS from 280 nm to 180 nm, as confirmed combining optical and morphological analysis. Modified screen-printed carbon electrodes (SPCE) with the as prepared MoSe2-NS were fabricated and applied for the determination of dopamine (DA) as an electroactive model analyte in the concentration ranging from 0.5 to 80 μM. DA is an important neurotransmitter for human beings and its deficiency can bring out various health diseases like Parkinson's and brain disorders, thus the development of simple DA sensors is highly demanding. Results demonstrated the better performances of the modified MoSe2 (5 krpm)/SPCE sensor compared to bare SPCE and the MoSe2 (1.5 krpm)/SPCE. With the objective to improve the electroanalytical performances toward dopamine, AuNPs-MoSe2-NS hybrid composite was also prepared, mixing AuNPs obtained by a green-reduction method with the MoSe2-NS. The developed AuNPs-MoSe2 (5 krpm)/SPCE sensor resulted the most promising with further improved sensitivity as compared to MoSe2/SPCE.''

July 2023: "A sensitive and selective non-enzymatic dopamine sensor based on nanostructured Co3O4-Fe2O3 hetero-junctions. "
Khan, M.; **Abid, K.**; Ferlazzo, A.; Bressi, V.; Espro, C.; Hussain, M.; Foti, A.; Gucciardi, P.; Neri, G.
Abstract: '' Chemosensors 2023, 11. DOI: **10.3390/chemosensors11070379**
In the present work, a study was carried out with the aim of enhancing the performance of electrochemical biosensors based on Co3O4:Fe2O3 heterojunctions. Specifically, the redox behavior of screen–printed carbon electrodes (SPCEs) modified with Co3O4:Fe2O3 (0.5 wt%:x wt%) nanocomposites, where x ranged from 0.1 to 0.5 wt%, was examined in detail. The hybrid nanocomposites were synthesized using the sol-gel auto-combustion method. Several characterization methods were performed to investigate the morphology, microstructure, and surface area of the pure Co3O4, pure Fe2O3, and the synthesized Co3O4:Fe2O3 nanocomposites. Using cyclic voltammetry (CV) tests, the electrochemical behavior of the modified electrodes toward the dopamine (DA) molecules was investigated. The modified Co3O4:Fe2O3, (0.5 wt%, x = 0.4 wt%)/SPCE resulted in a sensor with the best electrochemical performance toward DA. A high linear relationship between DA concentrations and the faradic current variation (ipa (μA) = 0.0736 + 0.1031 CDA (μA) and R2 = 0.99) was found in the range of 10–100 μM. The sensitivity value was computed to be 0.604 μA μM−1cm−2 and the limit of detection (LOD) 0.24 μM. Based on the characterization and electrochemical results, it can be suggested that the formation of Co3O4:Fe2O3 heterostructures provides a large specific surface area, an increased number of electroactive sites at the metal oxide interface and a p–n heterojunction, thus ensuring a remarkable enhancement in the electrochemical response towards DA.''

Deccember 2022: ''A novel 2D-GO@WS2 electrochemical platform for the determination of thiram fungicide''

Abid, K.; Iannazzo, D.; Celesti, C.; Khaskhoussi, A.; Foti, A.; Maalej, R.; Gucciardi, P. G.; Neri, G.
Journal of Environmental Sciences 2024, 136, 226–236. DOI: **10.1016/j.jes.2022.11.018.**
Abstract: '' In this paper, the determination of Thiram fungicide by a novel modified screen-printed carbon electrode (SPCE) fabricated modifying the working electrode (WE) with 2D-GO/WS2 nanohybrid composites, is reported. Scanning electron microscopy (SEM), Raman spectroscopy, and fluorescence analysis (PL) were used to reveal the morphological and microstructural characteristics of the 2D-GO/WS2 nanohybrids with different graphene oxide:tungsten disulphide (GO:WS2) ratio. Electrochemical characterization demonstrated that the 2D-WS2/GO nanohybrids having a GO:WS2 ratio = 2:1 shows the highest electrocatalytic activity towards oxidation of Thiram. The developed sensor permits the quantification of Thiram in the linear range 0.083-0.33 μM with a limit of detection (LOD) of 0.02 μM, which is below the legal limits for this fungicide in drinking water or foods. ''

November 2022:" Electrochemical and Sensing properties of AuNps-2D-MoS2/SPCE for Folic Acid Determination"

Abid, K.; Zribi, R.; Maalej, R.; Foti, A.; Khaskhoussi, A.; Gucciardi, P. G.; Neri, G.
FlatChem 2022, 36, 100433. DOI:**10.1016/j.flatc.2022.100433**.
Abstract: '' A simple and sensitive electrochemical sensor was developed for the detection of folic acid (FA) based on gold nanoparticles (AuNPs) dispersed on exfoliated MoS2 (2D-MoS2) nanosheets by a simple impregnation method. The prepared 2D-MoS2 and AuNPs-MoS2 samples were characterized by scanning electron microscopy (SEM-EDX), UV–vis, and Raman spectroscopy. Screen-printed carbon electrodes (SPCE) were modified by the 2D-MoS2 and AuNPs-MoS2 nanosheets and their electrochemical characteristics were investigated by means of electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) techniques and tested in the electroanalytical determination of folic acid (FA). The modified 2D-MoS2/SPCE was found to promote the FA electrooxidation process compared to bare SPCE. Instead, with the AuNPs-MoS2/SPCE sensor a different sensing mechanism, based on the inhibition of the Au NPs redox peaks current, has been found to be more effective. This behavior was due to the strong binding of FA on AuNPs, as probed by in situ ATR-FTIR and SERS measurements. The decrease of the anodic peak current of Au NPs with the concentration of FA provided an indirect signal which has been used here for detecting FA."

August 2022: Chapter "Properties of 2D materials " in Graphene and 2D Materials in Heat Transfer: Fundamentals and Applications
Abid, K.; Belkhir, N. H.;Wali.R; Maâlej, R
Abstract: ''Two -dimensional (2D) materials have become a prosperous research area since the exfoliation of graphene in 2004. This new class of materials has great potential for application in various fields such as medicine, forensic science, sensing… This is due to their outstanding features that have been either shown up or improved by shrinking the dimension. This chapter aims the description of the atomic structure of 2D materials such as molybdenum disulfide (MoS2), hexagonal-boron nitride (h-BN), reduced graphene oxide (rGO)... This specific structure reveals prominent features, which will be described in detail. Among these characteristics, we will aim at mechanical, thermal, tribological properties in addition to optoelectronic and magnetic features."

August 2020: ''Photoinduced Enhanced Raman Spectroscopy with Hybrid Au@WS2 Nanosheets"
Abid, K.; Belkhir, N. H.; Jaber, S. B.; Zribi, R.; Donato, M. G.; Di Marco, G.; Gucciardi, P. G.; Neri, G.; Maâlej, R.
J. Phys. Chem. C 2020, 124 (37), 20350–20358. DOI: **10.1021/acs.jpcc.0c04664**
Abstract: ''Two-dimensional (2D) layered transition-metal dichalcogenides (2DMX2) are materials with unique optoelectronic properties, high surface-to-volume ratio, and high carrier mobility. The combination of noble metal nanoparticles (MNPs) with 2DMX2 opens new avenues in conceiving more efficient plasmonic sensors, allowing one to optimize both electromagnetic and chemical signal enhancement. Photoinduced enhanced Raman spectroscopy (PIERS) exploits the electron migration from semiconductors to MNPs, upon UV light irradiation, to further boost the chemical enhancement in the surface-enhanced Raman scattering (SERS) of molecules deposited on hybrid 2DMX2–MNP nanostructures. Here, we propose a new PIERS sensor architecture based on tungsten disulfide (WS2) nanosheets produced by liquid-phase exfoliation (LPE) and functionalized with citrate-stabilized Au MPNs. Electron injection from WS2 to AuNPs is observed when the Au@WS2 is exposed to ultraviolet light, yielding an increase of the charge carriers' density ≈ 1.8%. The PIERS

sensor performances are tested by detecting 4-mercaptobenzoic acid at a concentration of 10 μM. The overall PIERS signal enhancement is ~106, whereas the photoactivation of WS2 yields a signal improvement of factor 4 with respect to SERS from Au@WS2 before UV irradiation. Our sensor is of low cost, easy to fabricate, and has the potential to detect biomolecules and chemical molecules at trace levels."

CONFERENCES AND SEMINAIRS

29-30 May 2023: 7th International Conference on Material Science and Engineering- Barcelona-Spain
Title: ''Novel sensitive platform toward thiram pesticide based on GO:WS2/SPCE"
Authors: **Khouloud Abid** [1,2,3,] Daniela Iannazzo [1], Consuelo Celesti [1], Amani Khaskhoussi [1], Antonino Foti [2], Ramzi Maalej [3], Pietro Giuseppe Gucciardi [2], Giovanni Neri [1*]
Oral presentation.
Role: presenter

22-25 May 2022: 7th International Conference on Bio-Sensing Technology- Sitges-Spain
Title: ''A New Electrochemical Like-Immunosensor Based on Au@MoS2 hybrid for The Detection of Vitamin B9"
Authors: **Khouloud Abid**[1,2,3,*], Ramzi Maâlej[1], Antonino Foti[3], Pietro G. Gucciardi[3], Giovanni Neri[2]
Oral presentation
Role: presenter

10-11 February 2022: RSC Chemical Nanoscience and Nanotechnology Early Careers Virtual Meeting - Online
Title: '' PIERS Hybrid Au@WS2 Nanosheets for Sensitive Detection of 4-Mercaptobenzoic Acid"
Authors: **K.Abid**[1], N.Hamza Belkhir+, R.Zribi[3, 4], S.Jaber[5], P.Gucciardi[6]. G.Neri[3,4], R.Maalej[1]
Poster presentation
Role: presenter

10-11 February 2022: AISEM - Online
Title: ''New Electrochemical Platform Au@MoS2 for Sensing Aim at Low Concentrations"
Authors: **Khouloud Abid**[1,2,3,4], Giovanni Neri[2,3], Pietro G. Gucciardi[4], Ramzi Maâlej[1]
Poster presentation
Role: presenter

4-7 February 2021: AMEG - Online
Title: 'New PIERS Substrate for The Detection at Low Traces Based on WS2 Nanosheets and Gold Nanoparticles"
Authors: **K.Abid**[1]*, N.Hamza Belkhir[1, 2], R.Zribi[1,3, 4], S.Jaber[5], P.Gucciardi[6]. G.Neri[3,4], R.Maalej[1]
Oral presentation
Role: presenter

07-09 December 2020 : 6th Nano Boston Conference -Online
Title: ''The efficiency of Photo-Induced Surface Enhanced Raman Spectroscopy (PIERS) WS2-AuNPs sensor in the detection of MBA residues"
Authors: **Khouloud Abid** [1*], Nour H.Belkhir[1, 2], Sultan B.Jaber[3,4], Rayhane Zribi[1,5,6], Pietro Gucciardi[7]. Giovani Neri[5,6], Ramzi Maâlej[1]
Poster presentation:
Role: presenter

29-31 October, 2019: 4th International Conference of Engineering Sciences for Biology and Medicine (ESBM)
Title: '' The SERS tool performance on MoS2-AuNPs"
Authors: **K.Abid**[1], N.Hamza Belkhir[1, 2], S.Jaber[3], R.Zribi[1, 4], P.Gucciardi[4]. G.Neri[5], R.Maalej[1]
Oral presentation:

Role: presenter

LECTURES

- Seminar at Department of Engineering of University of Messina-Italy.
Title: ''Vitamin B9 Electrochemical Determination Based on MX_2-Au NPs''
Event name: Doctorate course (XXXV cycle)
Date: 5th May 2022
Online teaching physics for high-school pupils on YouTube Channel Link:
https://www.youtube.com/watch?v=tBcZpnTdfx4&t=7s&ab_channel=NokhbaTN

OTHER ACTIVITIES

- **November 2022:** Editor member of American Journal of Chemical and Biochemical Engineering(AJCBE)

PERSONAL EXPERIENCES

2018-2019: Giving courses on mathematics and English for orphan kids in Sfax charity
Developing Website for my Family clothes brand

COMPETENCES

DIGITAL AND SOFTWARE COMPETENCES

Office365, Origin, Nova, DropView, VESTA, Chemdraw, ImageJ, LabSpec6, Gwydion, FPS, adobe photoshop. Average knowledge in html language, MATLAB and python

LANGUAGES

Arabic: Native language; **French:** B2 in speaking and B1 in writing; **English:** B2 B1 in speaking and B2 in writing; **Italian:** A2 in speaking and A1 in writing ; **Turkish:** A1 in speaking and A1 in writing.

Abid Khaoula