TECHNISCHE UNIVERSITÄT
IN DER KULTURHAUPTSTADT EUROPAS
CHEMNITZ

Faculty of Electrical Engineering and Information Technology
Institute for Microsystems and Semiconductor Technology
Professorship Measurement and Sensor Technology

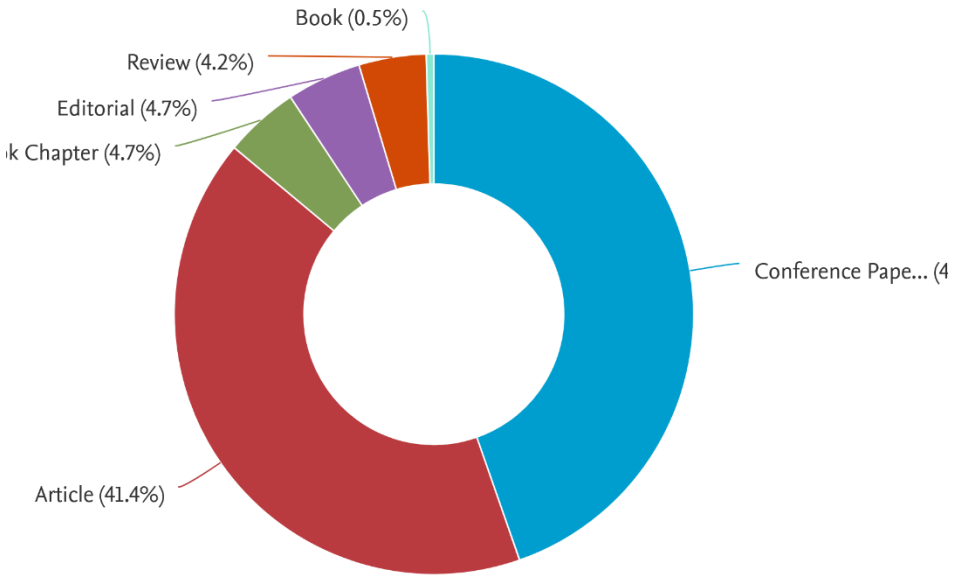
Publications Report

Editor: Prof. Dr.-Ing. Olfa Kanoun
Stand: 31.12.2023

Contents

1 Publications Overview

1.1 Documents by Type



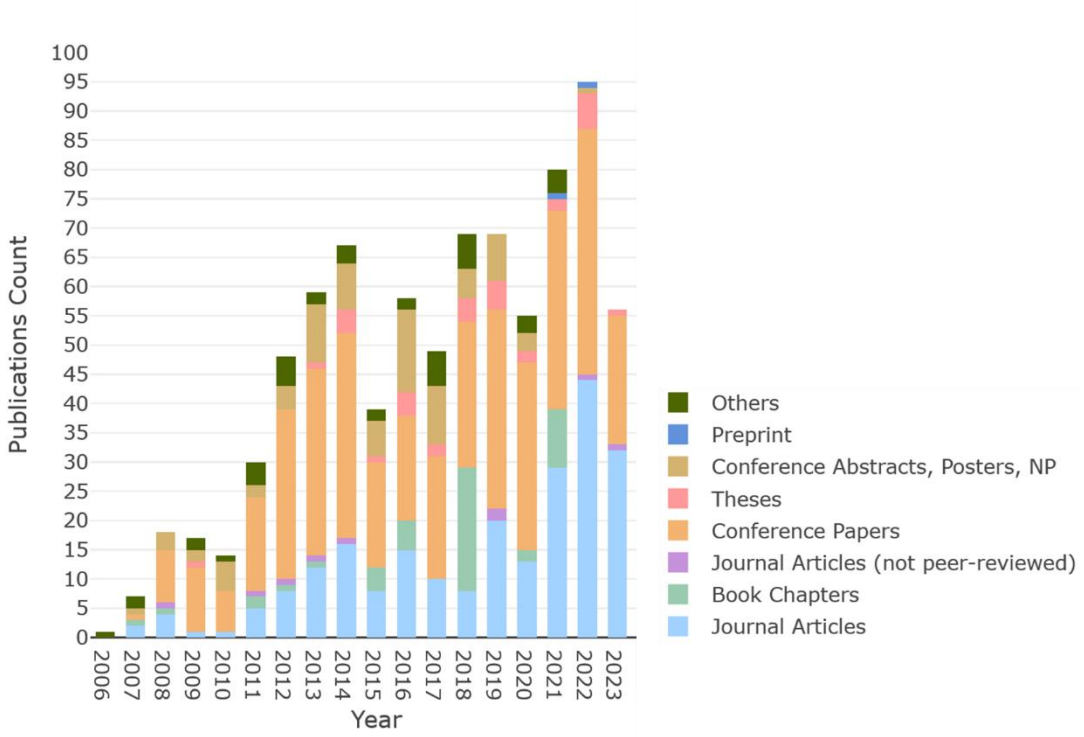
1.2 Main Keywords and Topics

- Energy Harvesting – Autonomous Wireless Sensors– Piezo Electric Converters – Inductive Power Transmission – Electromagnetic Energy Converter – Energy Management
- Compressive Sensing – Data Aggregation – Low Power Communication– Internet Of Things
- Nanocomposite and Filament Sensors based on: Multiwalled Carbon Nanotubes – Graphene – Polymers – Ceramics
- Pressure Sensors – Strain Sensors – Temperature Sensors – Humidity Sensors – Pressure Distribution Sensors – Temperature Self-Compensated Sensors – High-Temperature Sensors – RFID Sensors
- Functional Integration of Sensors in Structures – Materials and Textiles
- Nanogenerators – Piezoelectric Nanogenerator – Structural Health Monitoring
- Impedance Spectroscopy – Inductance Spectroscopy – Inductive Sensors – Bioimpedance Spectroscopy – Battery Diagnosis – Cable Identification – Cable Diagnosis – Electric Impedance Tomography (EIT) –Frequency Domain Analysis
- Electrochemical Sensors – Biosensors – Gas Sensors – Volatile Organic Compounds (VOC) – Cyclic Voltammetry – Electrochemical Impedance Spectroscopy – Electrodes
- Wearable Sensors – Gesture Recognition – Hand-gesture Recognition – American Sign Language – Surface Electromyography – Gait Analysis
- Machine Learning – Classification (of Information) – Learning Algorithms – Feature Extraction
- Industrial Applications – Industry 4.0 – Automotive applications – Environmental Applications – Medical Applications – Materials

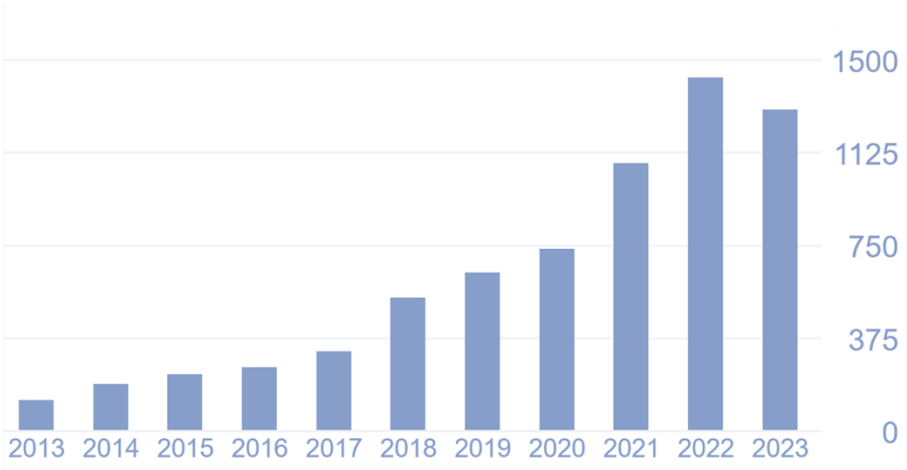
1.3 International Co-Authorship

Tunisia – France – Serbia – Brazil – Italy – Jordan – China - United States – India – Portugal – Romania - Russian Federation -

1.4 Publications per year



1.5 Citations per year



2 Impedance Spectroscopy and Measuring Systems

Energy Storage
ELSEVIER
MST
MEASUREMENT AND SENSOR TECHNOLOGY

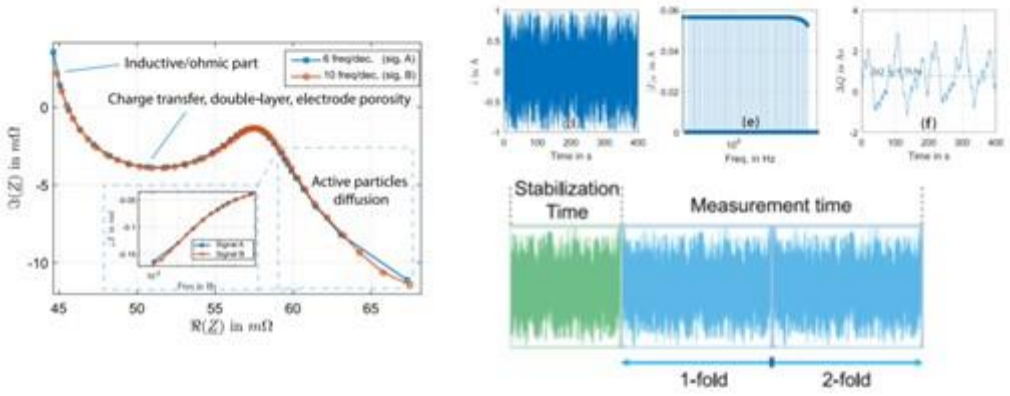
Research papers

On the design of multisine signals for maintaining stability condition in impedance spectroscopy measurements of batteries

Ahmed Yahia Kallel *, Olfa Kanoun

Measurement and Sensor Technology, Chemnitz University of Technology, Chemnitz, 09126, Germany

Journal of Energy Storage, Vol. 58, February 2023, 106267;
https://doi.org/10.1016/j.est.2022.106267



ABSTRACT

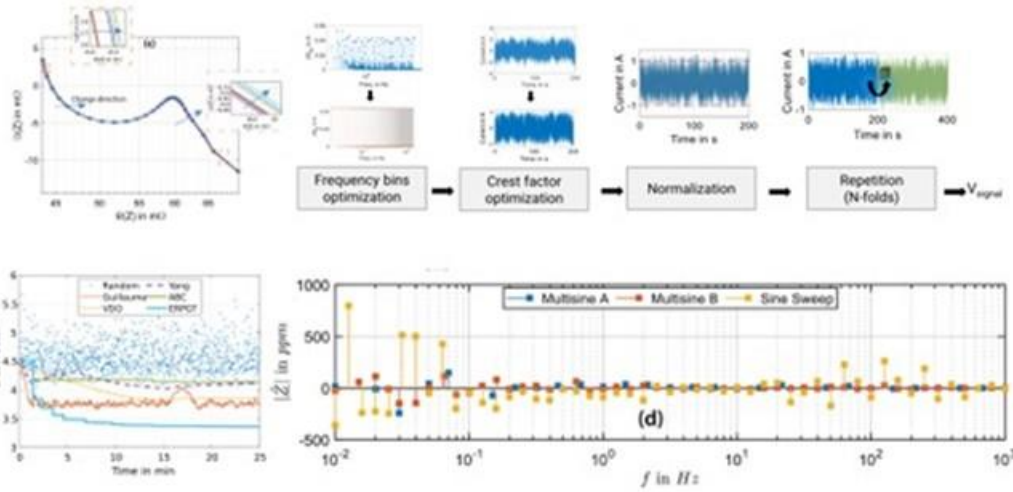
For measuring the impedance spectra of batteries, several challenges should be overcome to maintain the stability condition, especially at low frequencies in the mHz range. In this paper, we propose a novel design method for multisine excitation signals, which reduces measurement time and maintains battery stability. The novel excitation signals are structured in a dummy interval for considering the transient behavior of the battery and three folds of an optimized multisine signal. The system stability is evaluated by a consistency check based on the Linear Kramers–Kronig (LKK) method. Even if the sine sweep signals realize the highest signal power, they have a serious stability problem at low frequencies in the mHz region. The results show that the novel excitation signals outperform the often-used sinusoidal sweep signals by maintaining the stability condition during impedance measurements even at low frequencies in the mHz range. For example, for a signal with six frequencies/decade from 10 mHz to 1 kHz, a root means squares error of the LKK of 31.70 ppm could be realized instead of 201.21 ppm for the sine sweep, and the measurement time could be reduced to 315 s from 1440 s.

Journal of Energy Storage
ELSEVIER
MST MEASUREMENT AND SENSOR TECHNOLOGY

On the design of multisine signals for maintaining stability condition in impedance spectroscopy measurements of batteries

Ahmed Yahia Kallel *, Olfa Kanoun

J. En. Sources, Vol. 58, 2023, 106267, https://doi.org/10.1016/j.est.2022.106267



ABSTRACT

For measuring the impedance spectra of batteries, several challenges should be overcome to maintain the stability condition, especially at low frequencies in the mHz range. Even if the sine sweep signals realize the highest signal power, they lead to a severe stability problem at low frequencies in the mHz region. In this paper, we propose a novel design method for multisine excitation signals, which reduces measurement time and maintains battery stability. The novel excitation signals are structured in a dummy interval for considering the transient behavior of the battery and three folds of a multisine signal with an optimized crest factor, frequency bins, and measurement time. The system stability is evaluated by a consistency check based on the Linear Kramers–Kronig (LKK) method. The results show that the novel excitation signals outperform the often-used sinusoidal sweep signals by maintaining the stability condition during impedance measurements even at low frequencies in the mHz range. For example, for a signal with six frequencies/decade from 10 mHz to 1 kHz, a root means squares error of the LKK of 31.70 ppm could be realized instead of 201.21 ppm for the sine sweep, and the measurement time could be reduced to 315 s from 1440 s.

Keywords:
Impedance spectroscopy
System design
Excitation signals
Multisine signals
Lithium-ion batteries

IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT

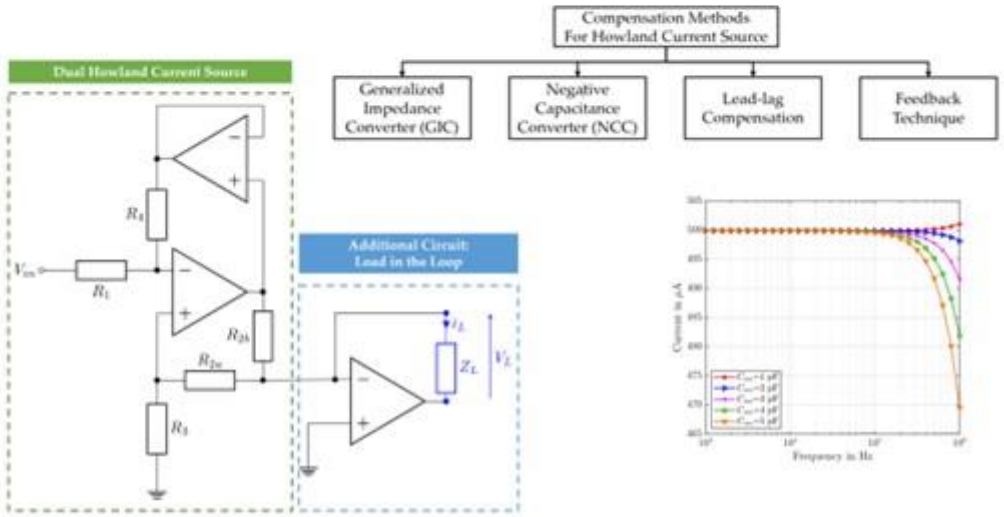
IEEE

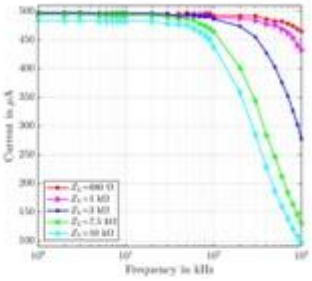
MST MEASUREMENT AND SENSOR TECHNOLOGY

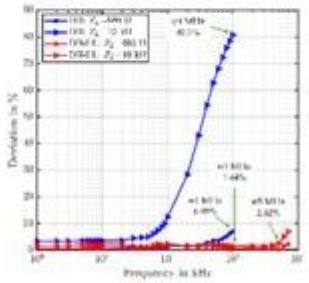
Load in the Loop Dual Howland Current Source for Wide Frequency Bandwidth and Wide Load Range Bioimpedance Measurements

Hanen Nouri*, Dhouha Bouchaala†, Yupei Zhao*, Ahmed Yahia Kallel* and Olfa Kanoun*

Trans. on Instrum. & Meas. (2023). https://doi.org/10.1109/TIM.2023.3325511







***Abstract*—The Howland current source is widely recognized as a high-efficiency voltage-controlled current source (VCCS) because it delivers a precise and stable current with a high output impedance over a wide frequency bandwidth. The Dual Howland (DH) is distinguished by a relatively high output impedance in comparison to the Enhanced Howland circuit (EH) has therefore the ability to supply higher loads. Nevertheless, at high frequencies, stray capacitances occurring mainly at the input of the operational amplifier and the circuit's output strongly affect its behavior. The output impedance strongly decreases, especially at frequencies higher than 100 kHz, and the flatness of the output current in dependence on the load is strongly affected. To overcome these challenges, we propose a novel dual Howland current source with load in the loop (DH-LL) completely isolating the load from the ground and maintaining the simplicity of the circuit. A simulation study shows that the output impedance (Z_{out}) of the DH-LL remains constant independent of the input stray capacitances. The influence of the output stray capacitance on the relative deviation of the output current decreases from 92 % in the case of DH to 2.7 % in the case of DH-LL. Experimental results show that the DH-LL reaches a frequency bandwidth of up to 5 MHz with a deviation of only 2.32 % for a varying load of up to 10 kΩ. Thereby, the relative deviation of the current amplitude, e. g. at 1 MHz, decreases from 6.98 % for DH to 1.44 % for DH-LL.**

***Index Terms*—Voltage Controlled Current Source (VCCS), Howland structure, bioimpedance spectroscopy, impedance spectroscopy, stray capacitance, compensation methods.**

JECR Journal of Electroceramics

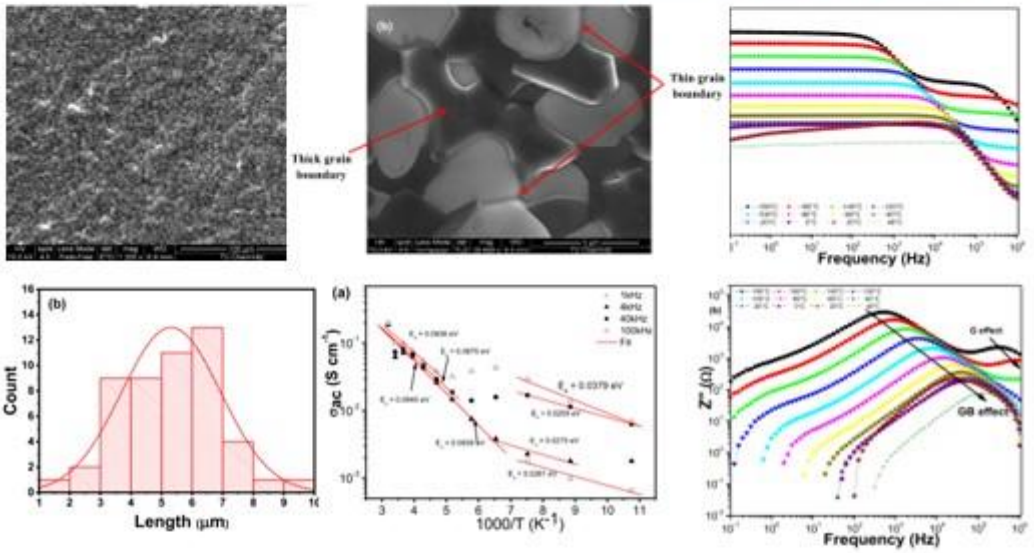
Springer

MST MEASUREMENT AND SENSOR TECHNOLOGY

Conduction mechanisms and complex impedance analysis in $La_{0.6}Sr_{0.4}FeO_3$ ceramic

R. Lataoui[1,2] · A. Triki[1] · S. Hcini[3] · A. Oueslati[4] · S. Zemni[2] · O. Kanoun[5]

J Electroceram **50**, 121–138 (2023). https://doi.org/10.1007/s10832-023-00310-4



Abstract

$La_{0.6}Sr_{0.4}FeO_3$ ceramic was elaborated by solid-state route. Preliminary room-temperature structural analysis evidences the sample formation in the orthorhombic structure and its phase purity. Electrical properties of the studied ceramic have been investigated according to dielectric measurements in the frequency range 10^{-1} - 10^6 Hz and the temperature range 93 - 313 K. Electrical conductivity curves exhibit a step-like behavior, at low temperatures, attributed to grain boundaries and grain contributions which are well described by the two Jonscher equations. The grains conduction mechanism is consistent with the thermally activated hopping of small polaron (SPH). Whereas, this mechanism is no longer satisfied for grain boundaries conduction mechanism at lower temperatures. Indeed, this latter is governed by the variable range hopping (VRH) model. This electrical conductivity analysis is further confirmed by the complex impedance formalism according to the obtained activation energies. Analysis of Nyquist plots at low temperatures has evidenced the presence of two grain boundaries effects attributed to the heterogeneous structure of $La_{0.6}Sr_{0.4}FeO_3$ grain boundary according to the morphological analysis. Such characteristic may be at the origin of the grain boundaries electrical conductivity mechanism change at low temperatures.

Keywords Dielectric measurements · $La_{0.6}Sr_{0.4}FeO_3$ ceramic · Complex impedance analysis · Morphological analysis · Electrical conductivity analysis

Measurement

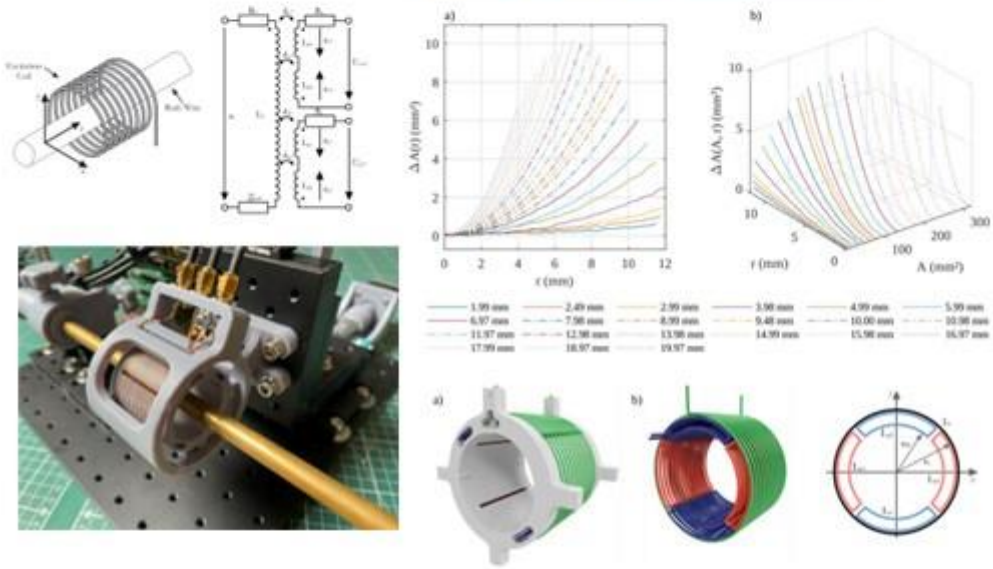
ELSEVIER

MST MEASUREMENT AND SENSOR TECHNOLOGY

Method to minimize the radial displacement dependency of an eddy-current based cross-sectional area measurement of hot-rolled rod and wire

Mario Radschun [a,*], Christoph Clemens [a], Annette Elisabeth Jobst [a], Andreas Hennig [a], Jörg Himmel [a], Olfa Kanoun [b]

Meas. (2023). 2023, 113629 | **DOI:** 10.1016/j.measurement.2023.113629



A B S T R A C T

The cross-sectional area of hot-rolled rod and wire must be measured to meet tight tolerances and high requirements of customers. An eddy-current based method utilizes a pass-through coil as a sensor element. It can measure the cross-sectional area by using the almost linear relationship between the coil reactance and the cross-sectional area of the rolled material. The lateral movement of the rod inside the coil causes deviations in the measured cross-section which must be minimized. This work outlines a successful approach for measuring the rod position within the coil using two differential pickup coils and minimizing the deviation using a simple algorithm.

Keywords:
Rod displacement
Cross-sectional area measurement
Rolled rod and wire
Eddy-current
Electromagnetic position measurement
Inductive measurement

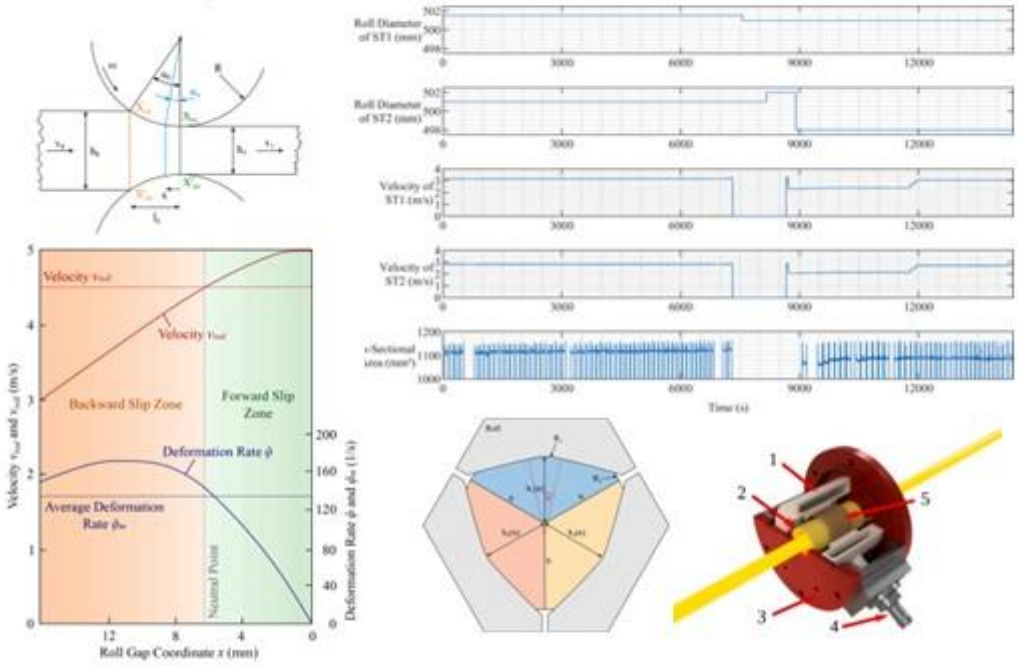
Measurement

ELSEVIER

MST
MEASUREMENT AND SENSOR TECHNOLOGY

Analysis of the roll imprint on the cross-sectional area of hot rolled wire rod by frequency spectroscopy

Annette Elisabeth Jobst [a,*], Mario Radschun [a], Christoph Clemens [a], Andreas Hennig [a], Olfa Kanoun [b], Jörg Himmel [a]



A B S T R A C T

This work presents an approach for analysing the sensor data of an eddy-current based cross-sectional area measurement for hot rod and wire steel in an innovative manner and for approximating the influence on the forward slip by longitudinal tensile forces between the mill stands. The method is based on frequency spectroscopy of the cross-sectional area of the rolled stock. The measurement data of three sensors already implemented in two hot rolling mills is used in order to obtain information out of the roll imprint on the cross-sectional area. Since measurement data from two measuring sites and from three sensors are evaluated, this allows statements to be made about the reliability and reproducibility of the measurement and shows that the method can be used for different rolling blocks such as 3-roll and 2-roll blocks. In addition, a mathematical model is presented which allows conclusions to be drawn about possible causes for certain characteristics in the measured frequency spectrum of the cross-sectional area.

Keywords:
Wire rod rolling mill
Hot rolling
Harsh environment
Cross-sectional area
Velocity
Forward slip
Frequency spectroscopy
Eddy-current sensor
Contactless
Non-destructive

IEEE potentials

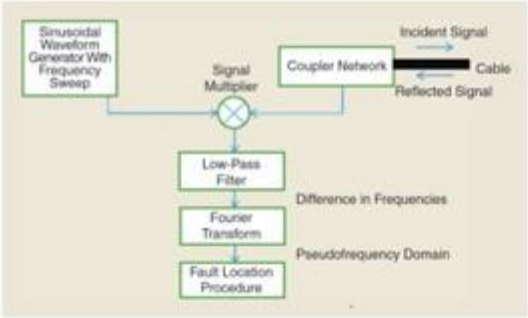
IEEE

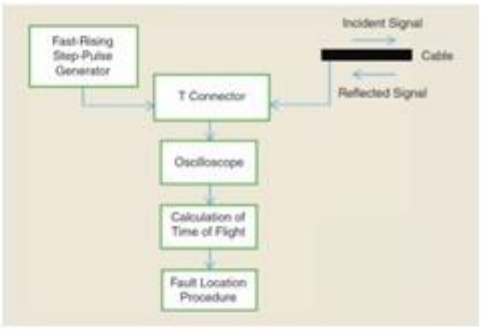
MST
MEASUREMENT AND SENSOR TECHNOLOGY

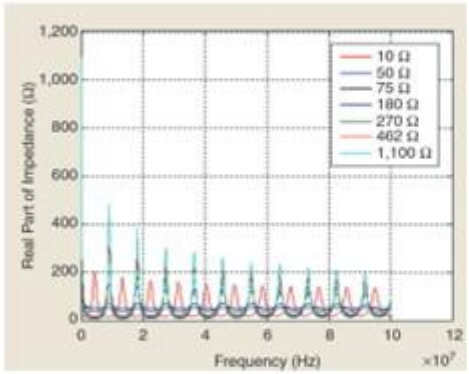
Location and characterization of faults in coaxial cables using reflectometry and impedance spectroscopy

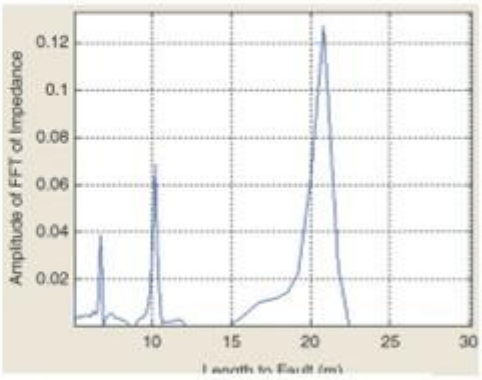
Padmanabhan Rajaraman, Qinghai Shi, and Olfa Kanoun

IEEE Potentials (Volume: 42, Issue: 2, March-April 2023),
https://doi.org/10.1109/MPOT.2014.2377272









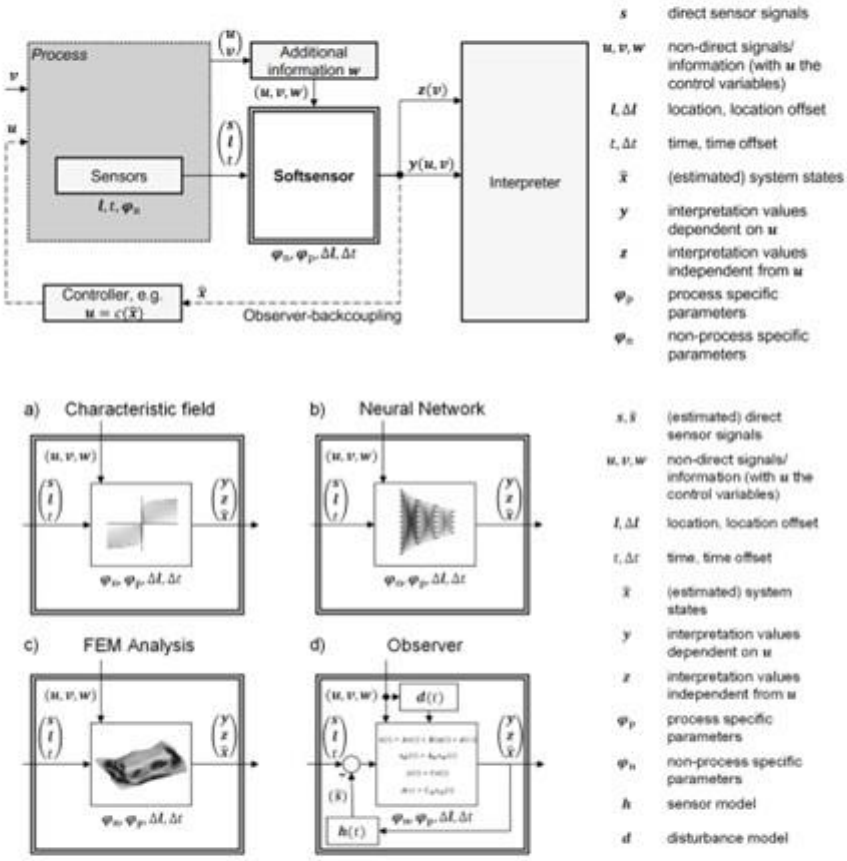
IEEE Keywords

Spectroscopy, Coaxial cables, Power cables, Frequency-domain analysis, Bandwidth, Reflectometry, Power system reliability

ADVANCES IN INDUSTRIAL AND MANUFACTURING ENGINEERING
Springer
MST MEASUREMENT AND SENSOR TECHNOLOGY

Softsensors: key component of property control in forming technology

Werner Homberg[1] · Bahman Arian[1] · Viktor Arne[3] · Thomas Borgert[1] · Alexander Brosius[2] · Peter Groche[3] · Christoph Hartmann[4] · Lukas Kersting[7] · Robert Laue[8] · Juri Martschin[6] · Thomas Meurer[5] · Daniel Spies[3] · A. Erman Tekkaya[6] · Ansgar Trächtler[1,7] · Wolfram Volk[4] · Frank Wendler[8] · Malte Wrobel[5]



Abstract

The constantly increasing challenges of production technology for the economic and resource-saving production of metallic workpieces require, among other things, the optimisation of existing processes. Forming technology, which is confronted with new challenges regarding the quality of the workpieces, must also organise the individual processes more efficiently and at the same time more reliably in order to be able to guarantee good workpiece quality and at the same time to be able to produce economically. One way to meet these challenges is to carry out the forming processes in closed-loop control systems using softsensors. Despite the many potential applications of softsensors in the field of forming technology, there is still no definition of the term softsensor. This publication therefore proposes a definition of the softsensor based on the definition of a sensor and the distinction from the observer, which on the one hand is intended to stimulate scientific discourse and on the other hand is also intended to form the basis for further scientific work. Based on this definition, a wide variety of highly topical application examples of various softsensors in the field of forming technology are given.

Keywords Forming · Process control · Softsensor · Observer

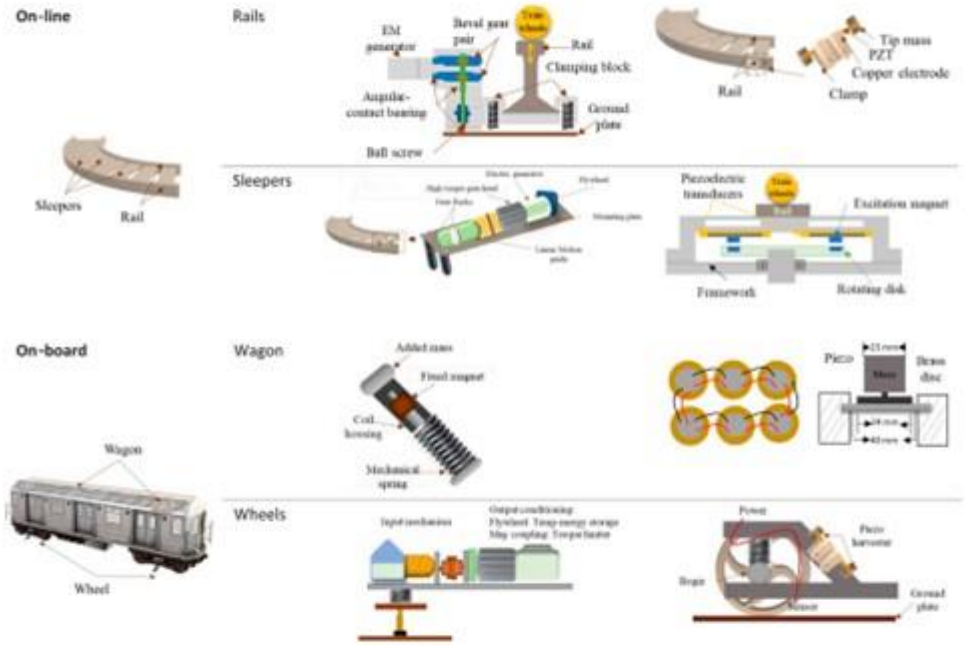
3 Wireless Energy-Aware Sensors

instrumentation & measurement MAGAZINE
IEEE
MST MEASUREMENT AND SENSOR TECHNOLOGY

Sustainable Wireless Sensor Networks for Railway Systems Powered by Energy Harvesting from Vibration

Olfa Kanoun, Ghada Bouattour, Sabrine Khriji, Kholoud Hamza, Abdallah Adawy, and Sonia Bradai

IEEE Instrumentation & Measurement Magazine **(2023),** 26(3), pp. 33-38,
DOI: https://doi.org/10.1109/MIM.2023.10121388



The railroad is a particularly efficient means of transporting passengers and goods. In this field, safety, reliability, and punctuality are of great importance, despite harsh environmental conditions and variable loads. Predictive maintenance of train wagons, rails, and stations is becoming increasingly essential [1] and requires massive use of sensors for measuring relevant quantities, such as acceleration, temperature, pressure, strain, and changes in railroad tracks and train wheels.

IEEE Keywords

Vibrations, Temperature sensors, Temperature measurement, Wireless sensor networks, Transducers, Wheels, Rail transportation

Sustainable Energy, Grids and Networks

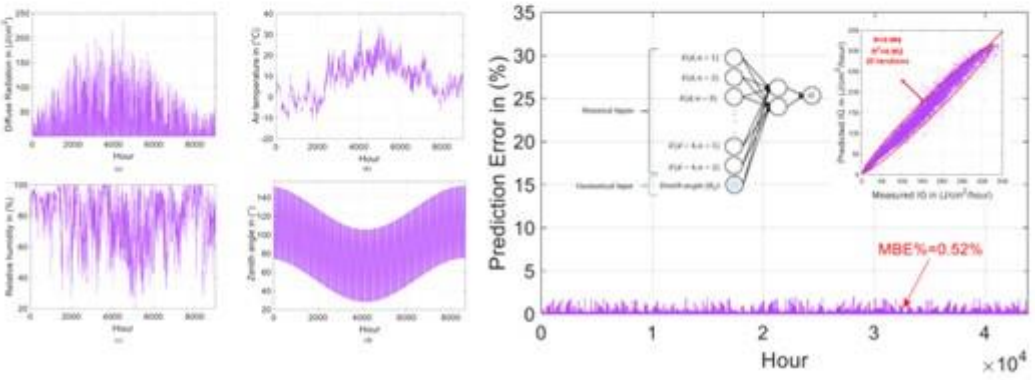
journal homepage: www.elsevier.com/locate/segan

MST MEASUREMENT AND SENSOR TECHNOLOGY

Development of predictive neural network with historical and geometrical inputs to minimize energy consumption in solar-fed wireless sensor networks

Murad Al-Omary [a,*], Christian Viehweger [b], Olfa Kanoun [b]

Sustainable Energy, Grids and Networks **2023**, *34*, 101040;
https://doi.org/10.1016/j.segan.2023.101040



A B S T R A C T

The effective operation of solar-supplied wireless sensor nodes is reached when a constant function with minimum energy consumption occurs. Accordingly, energy consumption management requires prior prediction of solar energy income. The accuracy of prediction contributes largely to maximizing or minimizing the energy consumed in those nodes. The moving average prediction algorithms show considerable errors due to sudden weather fluctuations. Additionally, the neural networks are applied only with historical inputs till now, accompanied by insufficient precision. Thus, they all prevent working effectively. This paper develops a predictive neural network with higher accuracy than the moving average algorithms and the neural networks of historical inputs. The developed neural network uses the zenith angle as additional geometrical input to the existing historical ones. The results showed a Mean Bias Error (MBE) of (0.52%) for the developed neural network. while (EWMA, WCMA, Pro-Energy, NN of 2 historical inputs, NN of 5 historical inputs, and NN of 19 historical inputs) appeared at (11.92%, 8.59%, 6.34%, 4.33%, 2.56%, and 1.08%), respectively. For a simulation period of one week, the developed neural network eliminated three hours of operation within the high consumption state (S3) in favor of the lower consumption state (S2) which maintains the constant function.

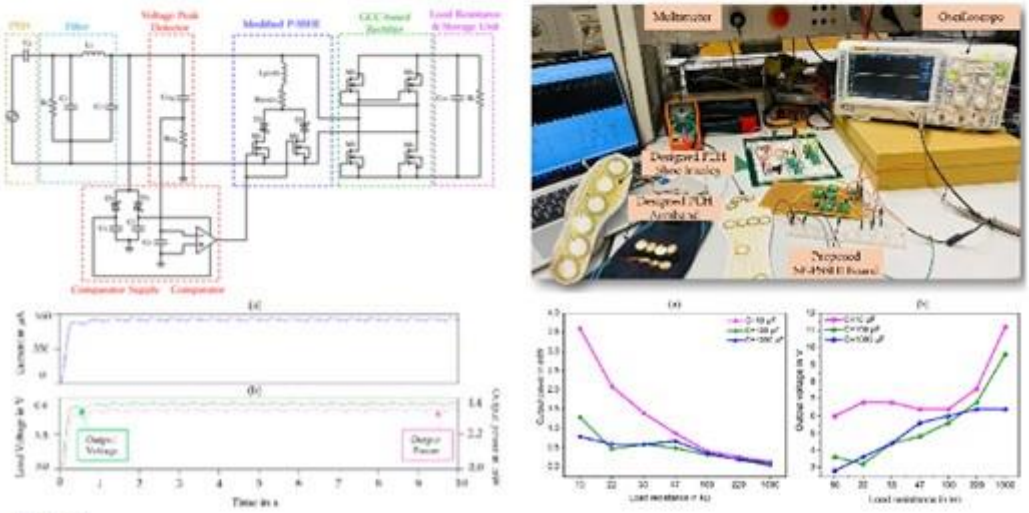
Keywords:
Wireless Sensor Networks (WSNs)
Energy Management
Global Irradiance (GI)
Solar Energy Harvesting
Neural Networks
Prediction Algorithms

sensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

Self-Powered Synchronized Switching Interface Circuit for Piezoelectric Footstep Energy Harvesting

by Meriam Ben Ammar [1,2,3,*], Salwa Sahnoun [2,3], Ahmed Fakhfakh [2,3], Christian Viehweger [1] and Olfa Kanoun [1,*]

Sensors **2023**, *23*(4), 1830; https://doi.org/10.3390/s23041830



Abstract

Piezoelectric Vibration converters are nowadays gaining importance for supplying low-powered sensor nodes and wearable electronic devices. Energy management interfaces are thereby needed to ensure voltage compatibility between the harvester element and the electric load. To improve power extraction ability, resonant interfaces such as Parallel Synchronized Switch Harvesting on Inductor (P-SSHI) have been proposed. The main challenges for designing this type of energy management circuits are to realise self-powered solutions and increase the energy efficiency and adaptability of the interface for low-power operation modes corresponding to low frequencies and irregular vibration mechanical energy sources. In this work, a novel Self-Powered (SP P-SSHI) energy management circuit is proposed which is able to harvest energy from piezoelectric converters at low frequencies and irregular chock like footstep input excitations. It has a good power extraction ability and is adaptable for different storage capacitors and loads. As a proof of concept, a piezoelectric shoe insole with six integrated parallel piezoelectric sensors (PEts) was designed and implemented to validate the performance of the energy management interface circuit. Under a vibration excitation of 1 Hz corresponding to a (moderate walking speed), the maximum reached efficiency and power of the proposed interface is 83.02% and 3.6 mW respectively for the designed insole, a 10 kΩ resistive load and a 10 µF storage capacitor. The enhanced SP-PSSHI circuit was validated to charge a 10 µF capacitor to 6 V in 3.94 s and a 1 mF capacitor to 3.2 V in 27.64 s. The proposed energy management interface has a cold start-up ability and was also validated to charge a (65 mAh, 3.1 V) maganese dioxide coin cell Lithium battery (ML 2032), demonstrating the ability of the proposed wearable piezoelectric energy harvesting system to provide an autonomous power supply for wearable wireless sensors.

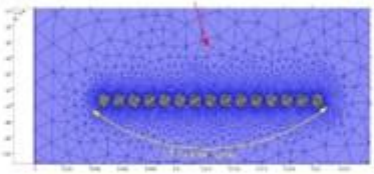
Keywords: wearable energy harvester; wearables; energy management; piezoelectric energy harvesters; self-powered; synchronized switching; vibration; human motion; footsteps; rectifiers; piezoelectric insole; piezoceramics; power supply

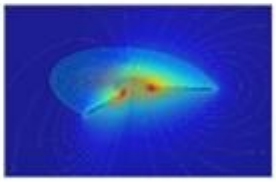
energies MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

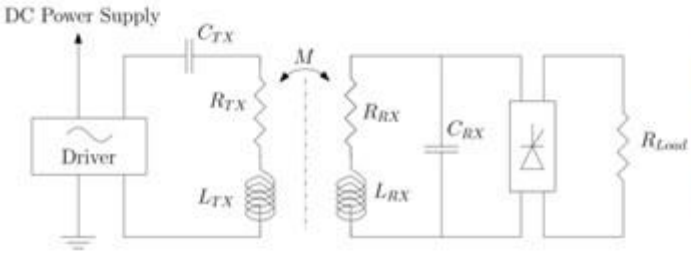
Model-Based Optimization of Spiral Coils for Improving Wireless Power Transfer

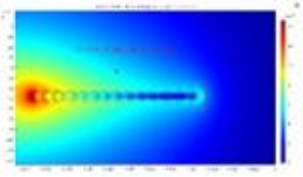
by Yosra Ben Fadhel [1,*,†], Ghada Bouattour [2,†], Dhouha Bouchaala [3], Nabil Derbel [4,†] and Olfa Kanoun [2,*,†]

Energies 2023, 16, 6886. https://doi.org/10.3390/en16196886









Abstract: Inductive wireless power transfer is a promising technology for powering smart wearable devices. The spiral coil shape is widely used in wireless power transfer applications. Nevertheless, during the coil design process, there are many challenges to overcome considering all the design constraints. The most important is to determine the optimal coil parameters (internal radius, external radius, spacing, wire width, and conductive wire) with the aim of obtaining the highest coil quality factor. Coil modeling is very important for the wireless power transfer system's efficiency. Indeed, it is challenging because it requires a high computational effort and has convergence problems. In this paper, we propose a new approach for the approximation of spiral coils through concentric circular turns to reduce the computational effort. The mathematical model determines the optimal coil parameters to obtain the highest coil quality factor. We have chosen the smart textile as an application. The system operates at a frequency of 100 Khz considering the Q_i guidelines. To validate this approach, we compared the approximated circular coil model with the spiral coil model through a finite element method simulation using the COMSOL software. The obtained results show that the proposed approximation reduces the complexity of the coil design process and performs well compared to the model corresponding to the spiral shape, without significantly modifying the coil inductance. For a wire width smaller than 1 mm, the total deviation is around 4% in terms of the coil quality factor in a predetermined domain of its parameters.

Keywords: smart textile; coil; magnetic resonant coupling; wireless power transfer; quality factor; resistance; inductance

International Journal of Information Technology

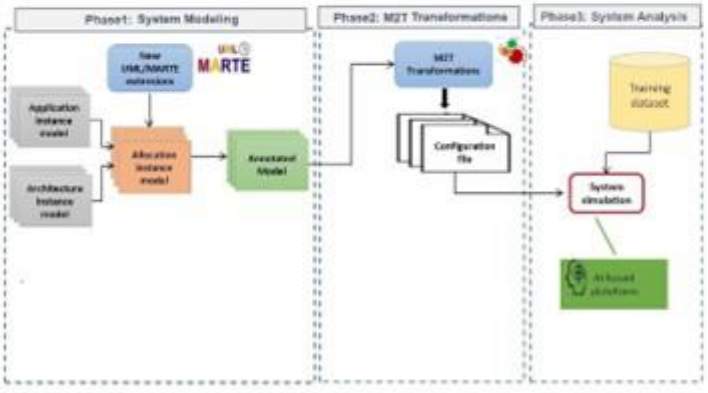
Springer

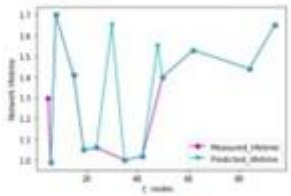
MST MEASUREMENT AND SENSOR TECHNOLOGY

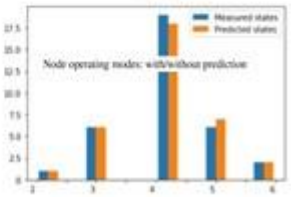
AI-based model driven approach for adaptive wireless sensor networks design

Nissaf Fredj[1,2] · Yessine Hadj Kacem[2] · Sabrine Khriji[1] · Olfa Kanoun[1] · Slim Hamdi[2,3] · Mohamed Abid[2]

Int. j. inf. tecnol. **15**, 1871–1883 (**2023**) https://doi.org/10.1007/







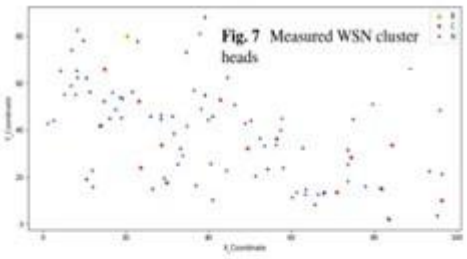


Fig. 7 Measured WSN cluster heads

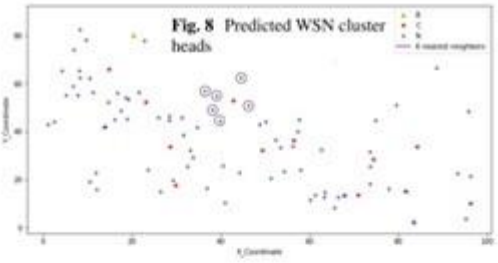


Fig. 8 Predicted WSN cluster heads

Abstract The development of IoT systems based WSN denotes a significant issue on providing intelligent capabilities to verify nodes behaviors and battery constraints. Existing AI-based works have been recently emerged for the analysis of dynamic WSN systems. Unfortunately, they failed to capture the design of dynamic intelligent WSN requirements at a high abstraction level. They provide AI solutions which are related to the target system and focus on specific problems without supporting reusability and interoperability. The Model Driven Engineering (MDE) and in particular the UML/MARTE profile become promising solutions for high-level abstraction to ease the design of WSN. We propose an AI-based model driven approach for the analysis and the prediction of WSN nodes behaviors and its interaction. It starts with a high-level specification based on the UML/MARTE profile, which describes the adaptation of WSN nodes and their interaction. Then, Model-to-Text (M2T) transformations are used to generate simulation scripts for analysis of WSN on a target AI-based platform. This later focuses on the prediction of WSN nodes behaviors, network clusters interaction and analysis of battery constraints. The prediction is based on training dataset which are collected from the German Weather Service (DWD) and measured within Measurement and Sensor Technology (MST) professorship, in the Technology University of Chemnitz.

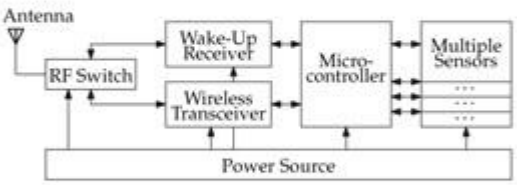
Keywords WSN · Adaptation · ML · K-NN · MDE · UML/MARTE

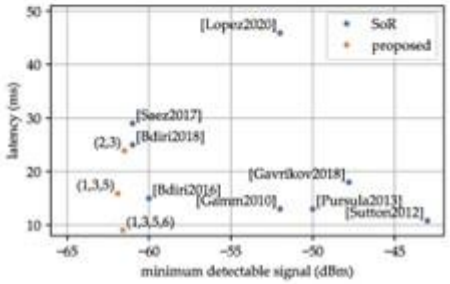
sensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

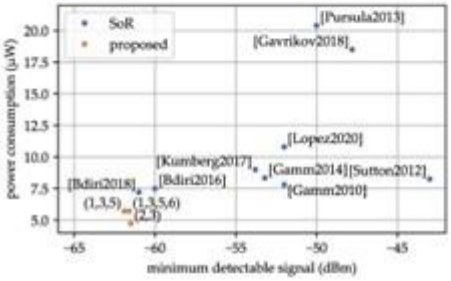
An Improved Wake-Up Receiver Based on the Optimization of Low-Frequency Pattern Matchers

by Robert Fromm [1,*], Olfa Kanoun [2] and Faouzi Derbel [1]

Sensors **2023**, *23*(19), 8188; https://doi.org/10.3390/s23198188







Abstract

Wake-up receivers are gaining importance in power-aware wireless sensor networks, as they significantly reduce power consumption during RF reception, enabling asynchronous communication with low latency. However, the performance of wake-up receivers still lags behind that of off-the-shelf RF transceivers. There is a growing demand for higher sensitivity, enhanced reliability, and lower latency while maintaining the lowest power consumption. In this article, our goal is to advance the performance of wake-up receivers based on off-the-shelf components and low-frequency pattern matchers. Through a systematic investigation, we proposed multiple improvements aimed at enhancing wake-up receiver performance and reliability. We introduced an improved passive envelope detector and realized a wake-up receiver for the 868 MHz band, which achieves a power consumption of 5.71 µW and latency of 9.02 ms. Our proposed wake-up receiver is capable of detecting signals down to an average power level of −61.6 dBm. These achievements represent significant advancements compared to the existing state of research on wake-up receivers based on low-frequency pattern matchers. Recent articles have not been able to attain such improved values in signal detection, power consumption, and latency.

Keywords: wireless sensor network; radio frequency; ultra-low power; Schottky diode; packet error rate; on-demand communication

4 Flexible and Nanocomposite Sensors

ACS APPLIED ELECTRONIC MATERIALS

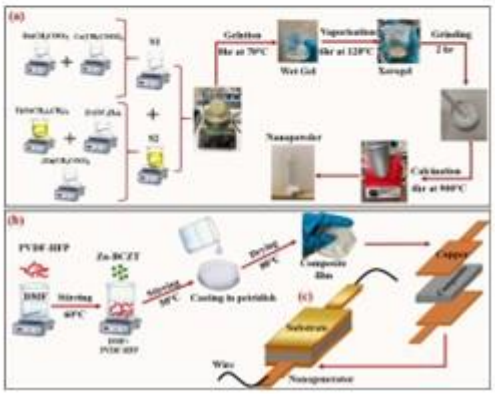
ACS Publications
Most Trusted. Most Cited. Most Read.

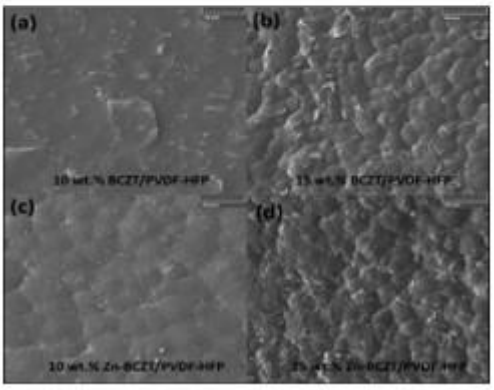
MST
MEASUREMENT AND SENSOR TECHNOLOGY

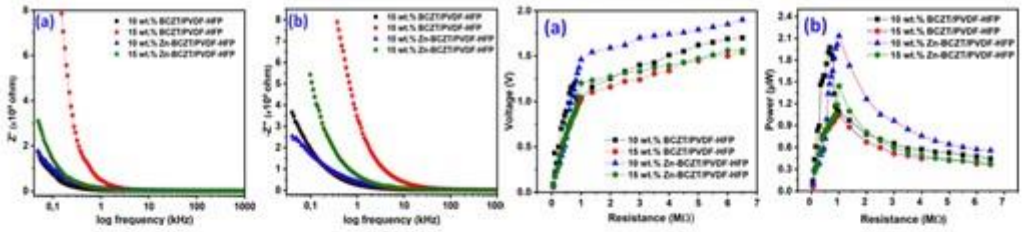
Robust and Flexible Piezoelectric Lead-Free Zn-BCZT/PVDF-HFP Nanogenerators for Wearable Energy Harvesting

Amina Ben Ayed,* Ayda Bouhamed,* Hanen Nouri, Najmeddine Abdelmoula, Hamadi Khemakhem, and Olfa Kanoun

ACS Appl. Electron. Mater. 2023, 5, 8, 4282–4295;
https://doi.org/10.1021/acsaelm.3c00562







ABSTRACT: Herein, flexible piezoelectric nanogenerators were fabricated based on polymer composites containing synthesized lead-free piezoceramics $Ba_{0.85}Ca_{0.15}Zr_{0.10}Ti_{0.90}O_3$ (BCZT) and zinc-doped BCZT (Zn-BCZT). Polyvinylidene fluoride-*co*-hexafluoropropylene (PVDF-HFP)-based composites were prepared through the solution casting method. The morphology and microstructure were investigated using Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). The distributions of crystallinity and β-phase fractions were also studied. Impedance measurements illustrate the accumulation of space charge in the high-frequency range and the existence of a non-Debye relaxation. The results show that a 10 wt % Zn-BCZT/PVDF-HFP nanogenerator can generate a maximum peak-to-peak output voltage of 3.3 V and a power of 2.13 μW for a load resistance of 1 MΩ under mechanical shaking. This nanogenerator can successfully harvest a good output voltage of up to 8 V under daily life movements such as walking. This study demonstrates the importance of doping zinc within BCZT to boost the piezoelectric performance as it contributes to minimize the crystallite particle size and enhance the crystal β-phase transformation of the polymer matrix. Hence, the 10 wt % Zn-BCZT/PVDF-HFP nanogenerator has great potential for use in wearable technologies. Furthermore, the nanogenerator demonstrates good stability over 1800 cycles of repetitive load and good reliability even after 1 year. These results indicate the robustness of the developed nanogenerator in practical applications.

KEYWORDS: *BCZT, Zn-BCZT, PVDF-HFP, composite, nanogenerator, energy harvesting*

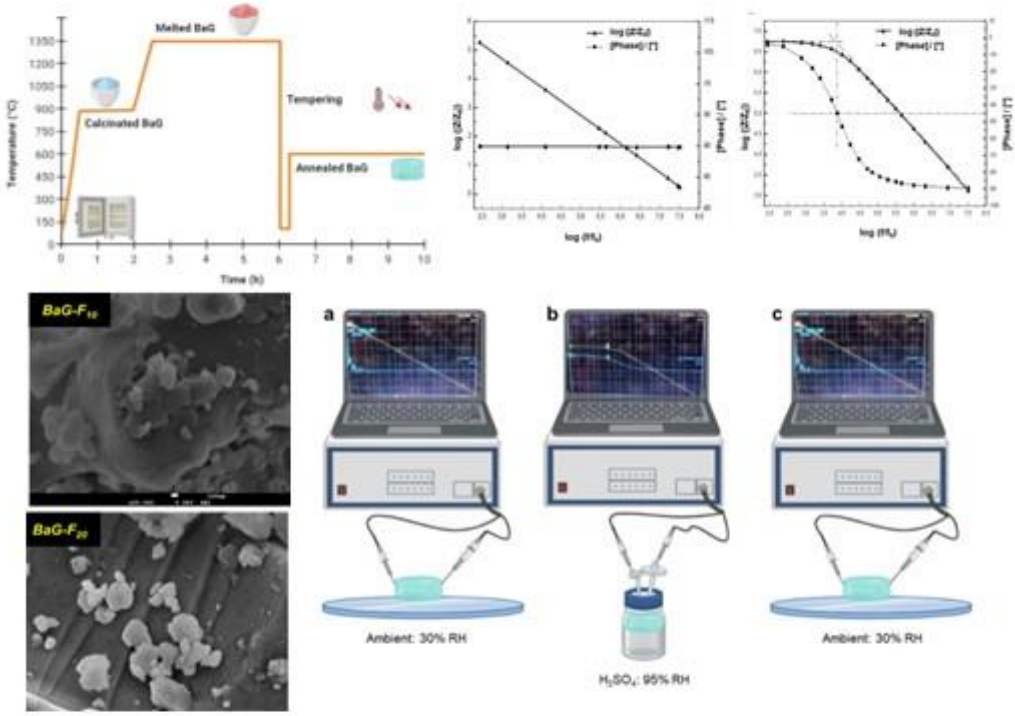
micromachines MDPI

MST MEASUREMENT AND SENSOR TECHNOLOGY

A Biodegradable Bioactive Glass-Based Hydration Sensor for Biomedical Applications

by Amina Gharbi [1,2,*], Ahmed Yahia Kallel [3], Olfa Kanoun [3], Wissem Cheikhrouhou-Koubaa [2], Christopher H. Contag [4], Iulian Antoniac [5], Nabil Derbel [1] and Nureddin Ashammakhi [4,*]

Micromachines **2023**, *14*(1), 226; https://doi.org/10.3390/mi14010226



Abstract

Monitoring changes in edema-associated intracranial pressure that complicates trauma or surgery would lead to improved outcomes. Implantable pressure sensors have been explored, but these sensors require post-surgical removal, leading to the risk of injury to brain tissue. The use of biodegradable implantable sensors would help to eliminate this risk. Here, we demonstrate a bioactive glass (BaG)-based hydration sensor. Fluorine (CaF_2) containing BaG (BaG-F) was produced by adding 5, 10 or 20 wt.% of CaF_2 to a BaG matrix using a melting manufacturing technique. The structure, morphology and electrical properties of the resulting constructs were evaluated to understand the physical and electrical behaviors of this BaG-based sensor. Synthesis process for the production of the BaG-F-based sensor was validated by assessing the structural and electrical properties. The structure was observed to be amorphous and dense, the porosity decreased and grain size increased with increasing CaF_2 content in the BaG matrix. We demonstrated that this BaG-F chemical composition is highly sensitive to hydration, and that the electrical sensitivity (resistive–capacitive) is induced by hydration and reversed by dehydration. These properties make BaG-F suitable for use as a humidity sensor to monitor brain edema and, consequently, provide an alert for increased intracranial pressure.

Keywords: bioactive glass; biodegradable; brain edema; capacitive sensor; hydration monitoring

materials

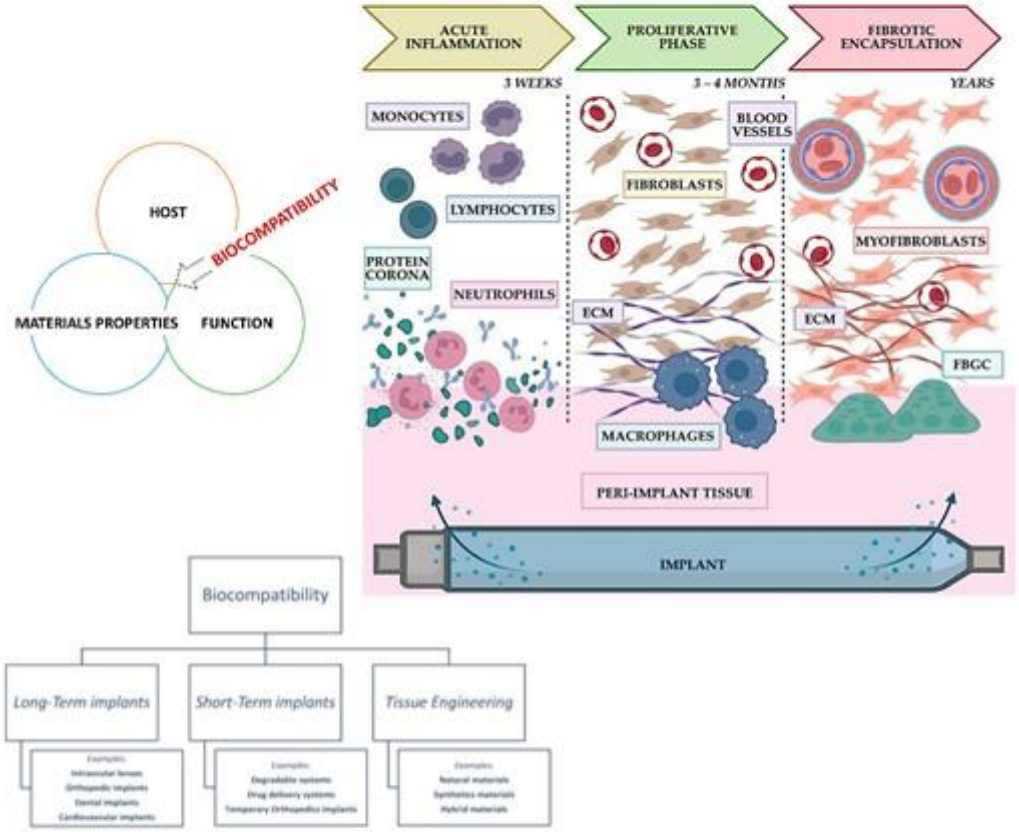
MDPI

MST
MEASUREMENT AND SENSOR TECHNOLOGY

Biocompatibility Testing for Implants: A Novel Tool for Selection and Characterization

by Walid Al-Zyoud [1,*], Dana Haddadin [1], Sameer Ahmad Hasan [1], Hussamaldeen Jaradat [2] and Olfa Kanoun [2,*]

Materials **2023**, *16*(21), 6881; https://doi.org/10.3390/ma16216881



Abstract

This review article dives into the complex world of biocompatibility testing: chemical, mechanical, and biological characterization, including many elements of biocompatibility, such as definitions, descriptive examples, and the practical settings. The focus extends to evaluating standard documents obtained from reliable organizations; with a particular focus on open-source information, including FDA-USA, ISO 10933 series, and TÜV SÜD. We found a significant gap in this field: biomaterial scientists and those involved in the realm of medical device development in general, and implants in particular, lack access to a tool that reorganizes the process of selecting the appropriate biocompatibility test for the implant being examined. This work progressed through two key phases that aimed to provide a solution to this gap. A straightforward "yes or no" flowchart was initially developed to guide biocompatibility testing decisions based on the previously accumulated information. Subsequently, the Python code was employed, generating a framework through targeted questions. This work reshapes biocompatibility evaluation, bridging theory and practical implementation. An integrated approach via a flowchart and the Python code empowers stakeholders to navigate biocompatibility testing effortlessly. To conclude, researchers are now better equipped for a safer, more effective implant development, propelling the field towards improved patient care and innovative progress.

Keywords: biocompatibility; implants; mechanical property; health

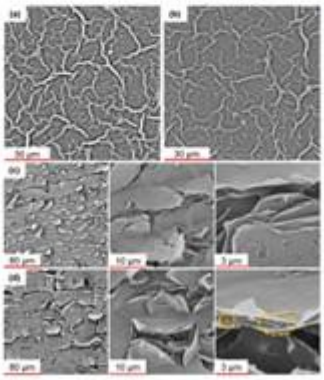
5 Electrochemical Sensors

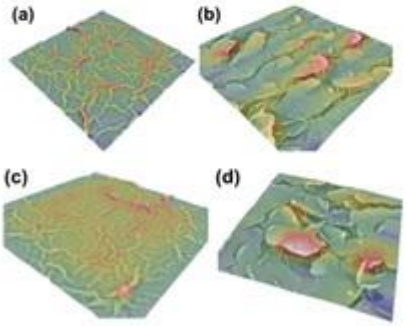
nanomaterials MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

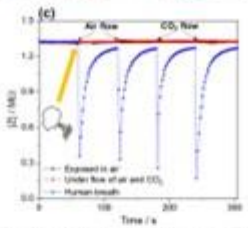
Ultra-Sensitive and Fast Humidity Sensors Based on Direct Laser-Scribed Graphene Oxide/Carbon Nanotubes Composites

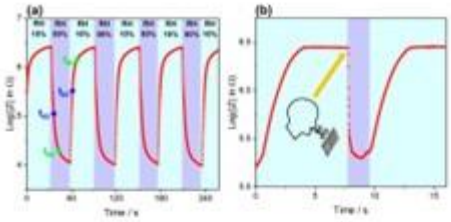
by Ammar Al-Hamry [1,*], Tianqi Lu [1], Haoran Chen [1], Anurag Adiraju [1], Salem Nasraoui [1], Amina Brahem [1], Danica Bajuk-Bogdanović [2], Saddam Weheabby [1], Igor A. Pašti [2] and Olfa Kanoun [1,*]

Nanomaterials **2023**, *13*(9), 1473; https://doi.org/10.3390/nano13091473









In this paper, the relative humidity sensor properties of graphene oxide (GO) and graphene oxide/multiwalled nanotubes (GO/MWNTs) composites have been investigated. Composite sensors were fabricated by direct laser scribing and characterized using UV-vis-NIR, Raman, Fourier transform infrared, and X-ray photoemission spectroscopies, electron scanning microscopy coupled with energy-dispersive X-ray analysis, and impedance spectroscopy (IS). These methods confirm the composite homogeneity and laser reduction of GO/MWNT with dominant GO characteristics, while ISresults analysis reveals the circuit model for rGO-GO-rGO structure and the effect of MWNT on the sensor properties. Although direct laser scribing of GO-based humidity sensor shows an outstanding response ($|\Delta Z|/|Z|$ up to 638,800%), a lack of stability and repeatability has been observed. GO/MWNT-based humidity sensors are more conductive than GO sensors and relatively less sensitive ($|\Delta Z|/|Z|$ = 163,000%). However, they are more stable in harsh humid conditions, repeatable, and reproducible even after several years of shelf-life. In addition, they have fast response/recovery times of 10.7 s and 9.3 s and an ultra-fast response time of 61 ms when abrupt humidification/dehumidification is applied by respiration. All carbon-based sensors' overall properties confirm the advantage of introducing the GO/MWNT hybrid and laser direct writing to produce stable structures and sensors.

Keywords: laser direct writing; reduced graphene oxide; carbon nanotubes; nanocomposite; humidity sensor; impedance spectroscopy

ChemElectroChem

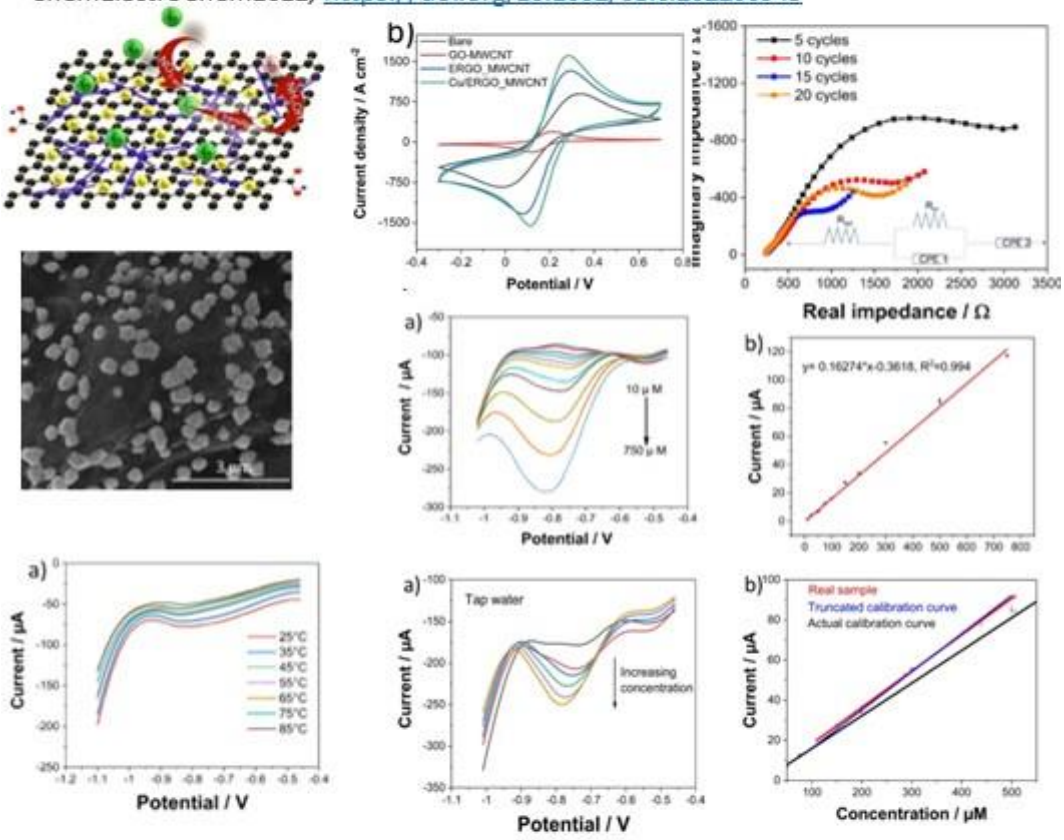
ELSEVIER

MST MEASUREMENT AND SENSOR TECHNOLOGY

Optimized Reduction of a Graphene Oxide-MWCNT Composite with Electrochemically Deposited Copper Nanoparticles on Screen Printed Electrodes for a Wide Range of Detection of Nitrate

Adiraju Anurag,*[a] Ammar Al-Hamry,[a] Yashwanth Attuluri,[a] Saravanan Palaniyappan,[b] Guntram Wagner,[b] Doreen Dentel,[c] Christoph Tegenkamp,[c] and Olfa Kanoun*[a]

ChemElectroChem2022, https://doi.org/10.1002/celc.202200945



In this report, we demonstrate the capability of electrochemically deposited copper (Cu) nanoparticles on electrochemically reduced graphene oxide (ERGO)-multiwalled carbon nanotubes (MWCNT) composite on screen printed carbon electrodes (SPCE) for electrochemical detection of nitrate. Prior to the detection, extensive fundamental investigations on the electrochemical reduction of GO on SPCE and role of MWCNT in the reduction process and the degree of reduction have been carried out which has not been previously reported. Profiting from the complementary information obtained from electrochemical impedance spectroscopy, Raman spectroscopy, and cyclic voltammetry (CV), the role of MWCNT and optimal number of scans in CV (15 scans) for the reduction was obtained. The determination of nitrate on Cu/ERGO-MWCNT/SPCE was performed by square wave voltammetry and shows a wide linear range from 10 to 750 µM and low limit of detection of 3.3 µM, thereby enhancing the applicability of the developed electrode in the regions of low and high concentrations as well. The electrode was tested in tap water and the analytical capability was compared using F-test and matrix effect (4.8%), which highlights excellent analytical ability of the Cu/ERGO-MWCNT modified electrodes to detect nitrate.

Keywords: Copper nanoparticles · Electrochemical impedance spectroscopy · Graphene oxide-multiwalled carbon nanotubes · Nitrate · Raman spectroscopy

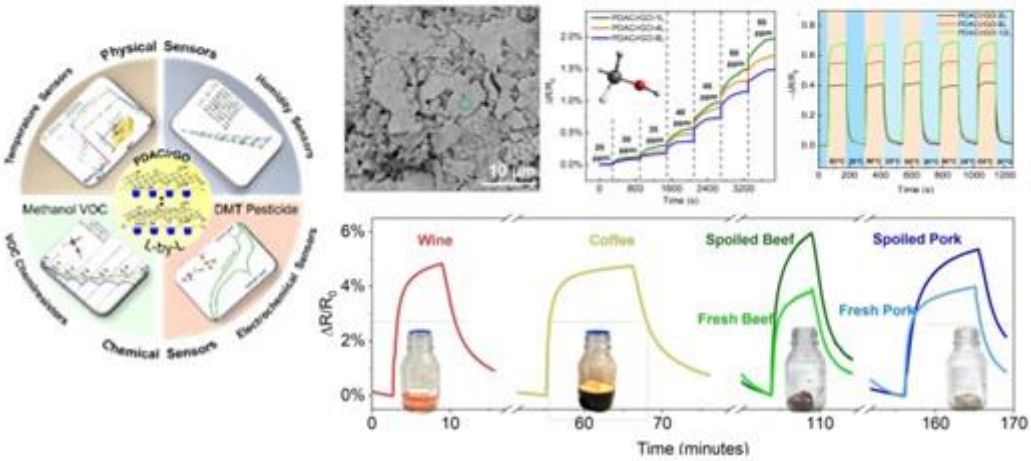
foods MDPI

MST MEASUREMENT AND SENSOR TECHNOLOGY

Layer-by-Layer Deposited Multi-Modal PDAC/rGO Composite-Based Sensors

Ammar Al-Hamry [1], Tianqi Lu [1], Jing Bai [1], Anurag Adiraju [1], Tharun K. Ega [1], Igor A. Pašti [2] and Olfa Kanoun [1,*]

Foods **2023**, *12*(2), 268; https://doi.org/10.3390/foods12020268



Abstract: Different environmental parameters, such as temperature and humidity, aggravate food spoilage, and different volatile organic compounds (VOCs) are released based on the extent of spoilage. In addition, a lack of efficient monitoring of the dosage of pesticides leads to crop failure. This could lead to the loss of food resources and food production with harmful contaminants and a short lifetime. For this reason, precise monitoring of different environmental parameters and contaminations during food processing and storage is a key factor for maintaining its safety and nutritional value. Thus, developing reliable, efficient, cost-effective sensor devices for these purposes is of utmost importance. This paper shows that Poly-(diallyl-dimethyl ammonium chloride)/reduced Graphene oxide (PDAC/rGO) films produced by a simple Layer-by-Layer deposition can be effectively used to monitor temperature, relative humidity, and the presence of volatile organic compounds as indicators for spoilage odors. At the same time, they show potential for electrochemical detection of organophosphate pesticide dimethoate. By monitoring the resistance/impedance changes during temperature and relative humidity variations or upon the exposure of PDAC/rGO films to methanol, good linear responses were obtained in the temperature range of 10–100 °C, 15–95% relative humidity, and 35 ppm–55 ppm of methanol. Moreover, linearity in the electrochemical detection of dimethoate is shown for the concentrations in the order of 10^2 μmol dm^{-3}. The analytical response to different external stimuli and analytes depends on the number of layers deposited, affecting sensors' sensitivity, response and recovery time, and long-term stability. The presented results could serve as a starting point for developing advanced multi-modal sensors and sensor arrays with high potential for analytical applications in food safety and quality monitoring.

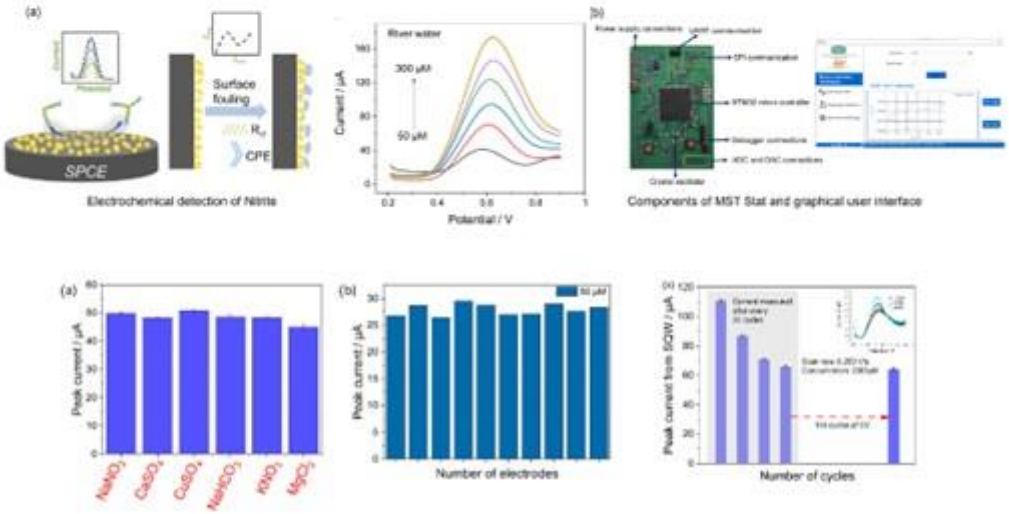
Keywords: multi-modal sensor; poly(diallyl dimethyl ammonium chloride); reduced graphene oxide; layer-by-layer deposition; temperature sensor; relative humidity sensor; volatile organic compounds; electrochemical senor

sensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

Towards Embedded Electrochemical Sensors for On-Site Nitrite Detection by Gold Nanoparticles Modified Screen Printed Carbon Electrodes

by Anurag Adiraju [1,*], Rohan Munjal [1,*], Christian Vielweger [1], Ammar Al-Hamry [1], Amina Brahem [1], Jawaid Hussain [1], Sanhith Kommisetty [1], Aditya Jalasutram [1], Christoph Tegenkamp [2] and Olfa Kanoun [1,*]

Sensors **2023**, *23*(6), 2961; https://doi.org/10.3390/s23062961



Abstract

The transition of electrochemical sensors from lab-based measurements to real-time analysis requires special attention to different aspects in addition to the classical development of new sensing materials. Several critical challenges need to be addressed including a reproducible fabrication procedure, stability, lifetime, and development of cost-effective sensor electronics. In this paper, we address these aspects exemplarily for a nitrite sensor. An electrochemical sensor has been developed using one-step electrodeposited (Ed) gold nanoparticles (EdAu) for the detection of nitrite in water, which shows a low limit of detection of 0.38 µM and excellent analytical capabilities in groundwater. Experimental investigations with 10 realized sensors show a very high reproducibility enabling mass production. A comprehensive investigation of the sensor drift by calendar and cyclic aging was carried out for 160 cycles to assess the stability of the electrodes. Electrochemical impedance spectroscopy (EIS) shows significant changes with increasing aging inferring the deterioration of the electrode surface. To enable on-site measurements outside the laboratory, a compact and cost-effective wireless potentiostat combining cyclic and square wave voltammetry, and EIS capabilities has been designed and validated. The implemented methodology in this study builds a basis for the development of further on-site distributed electrochemical sensor networks.

Keywords: electrochemical sensors; electrochemical impedance spectroscopy; gold nanoparticles; electrodeposition; nitrite; potentiostat; groundwater; stability of electrochemical sensors

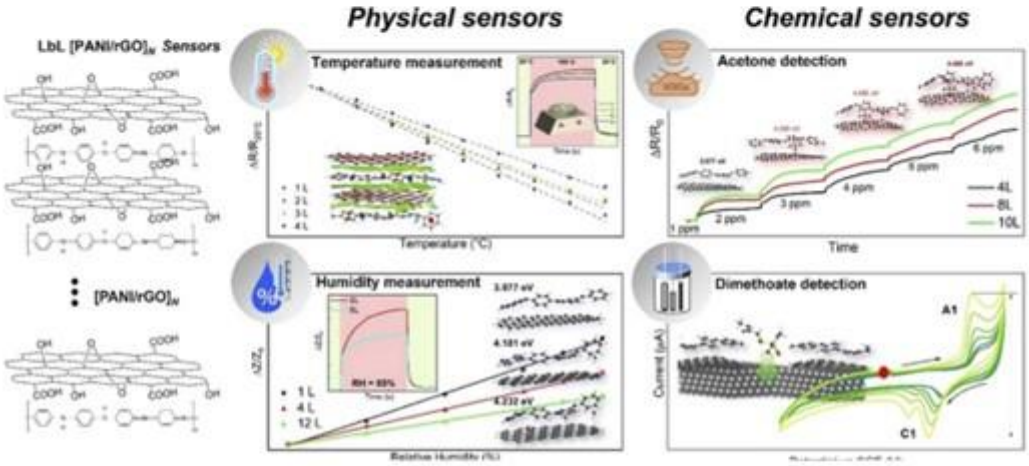
Keywords: electrochemical sensors; electrochemical impedance spectroscopy; gold nanoparticles; electrodeposition; nitrite; potentiostat; groundwater; stability of electrochemical sensors

Sensors and Actuators B: Chemical
Volume 390, 1 September 2023, 133988

Versatile sensing capabilities of layer-by-layer deposited polyaniline-reduced graphene oxide composite-based sensors

Ammar Al-Hamry [a], Tianqi Lu [a], Jing Bai [a], Anurag Adiraju [a], Tharun K. Ega [a], L.G. Paterno [b], Igor A. Pašti [c], Olfa Kanoun [a]

Sensors & Actuators B: Chemical **2023**, , *390, 133988*;
https://doi.org/10.1016/j.snb.2023.133988



A B S T R A C T

Precise temperature, humidity, and organic pollutants monitoring are required for industrial, environmental and medical applications. The interesting properties of polyaniline for sensors, such as environmental responsiveness and stability, combined with the large surface area and tunable properties of graphene oxide, offer excellent prospects for the development of sensor materials. In this paper, we show that HCl-doped polyaniline/reduced graphene oxide (PANI/rGO) layer-by-layer deposition and subsequent reduction can be used as resistive sensors for temperature, humidity, acetone, and electrochemical sensors for organophosphate detection in aqueous solutions. Sensors were characterized using atomic force and scanning electron microscopies and energy-dispersive x-ray and Raman spectroscopies, and impedance spectroscopy complemented by semi-empirical quantum chemical calculations. Reduction temperature and bilayer numbers influence PANI/rGO sensor characteristics significantly. The results show that only one PANI/rGO bilayer is needed to provide a temperature coefficient of resistance of − 0.758 $°C^{-1}$ and 37% sensitivity at 95% relative humidity. PANI/rGO shows potential for electrochemical detection of dimethoate affected by the number of bilayers and reduction temperature. The response to acetone vapor is linear from 1 to 60 ppm and detectable at 1 ppm. The sensors do not respond to methanol and some other volatile organic compounds (VOCs) at the same concentration. Food monitoring with total VOCs detection was successfully demonstrated. PANI/rGO sensors feature versatile sensing capabilities, making them feasible due to their rapid production and low cost.

Keywords

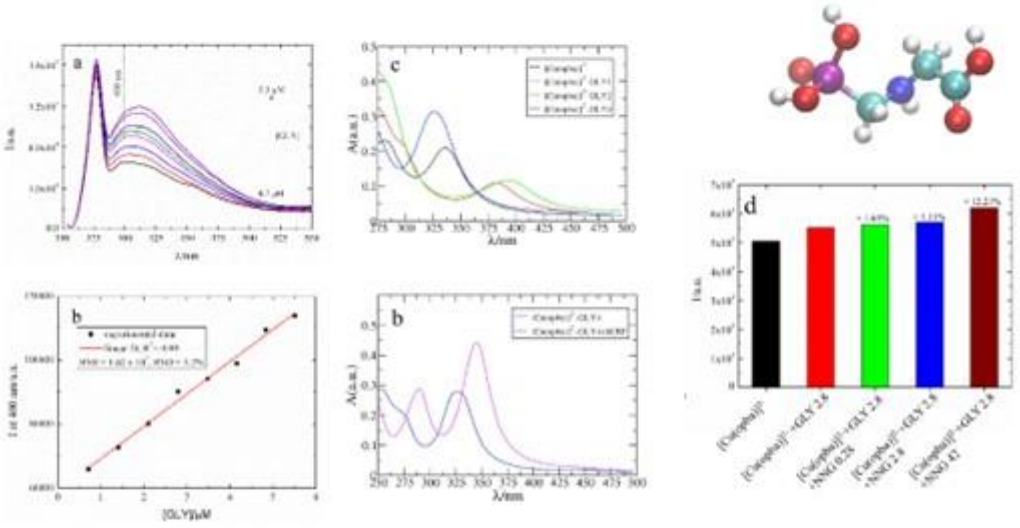
Multimodal sensor, polyaniline; Reduced graphene oxide; Temperature; Relative humidity; Volatile organic compounds; Pesticides

chemosensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

Experimental-Theoretical Approach for the Chemical Detection of Glyphosate and Its Potential Interferents Using a Copper Complex Fluorescent Probe

by Guilherme Martins [1], Karolyne V. Oliveira [1], Saddam Weheabby [2], Ammar Al-Hamry [2], Olfa Kanoun [2], Tobias Rüffer [3], Benedito J. C. Cabral [1,4] and Leonardo G. Paterno [1,*]

Chemosensors **2023**, *11*(3), 194; https://doi.org/10.3390/chemosensors11030194



Abstract

The present contribution proposes an optical method for the detection of glyphosate (GLY) using a Cu(II) bis-(oxamate) complex ($[Cu(opba)]^{2-}$) as the fluorescent probe. It wa found that in acetonitrile solution, its fluorescence increases in the presence of GLY and scales linearly (R^2 = 0.99) with GLY concentration in the range of 0.7 to 5.5 µM, which is far below that established by different international regulations. The probe is also selective to GLY in the presence of potential interferents, namely aminomethyl phosphonic acid and *N*-nitrosoglyphosate. Theoretical results obtained by time-dependent density functional theory coupled to a simplified treatment of the liquid environment by using a self-consistent reaction-field revealed that GLY molecules do not coordinate with the central Cu^{2+} ion of $[Cu(opba)]^{2-}$; instead, they interact with its peripheral ligand through hydrogen bond formation. Thereby, GLY plays mainly the role of the proton donor. The results also suggest that GLY increases the dielectric constant of the medium when it contributes to the stabilization of the excited state of the $[Cu(opba)]^{2-}$ and enhancement of its fluorescence.

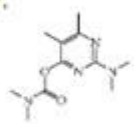
Keywords: copper complexes; dielectric medium; fluorescent sensor; herbicides; hydrogen bonding

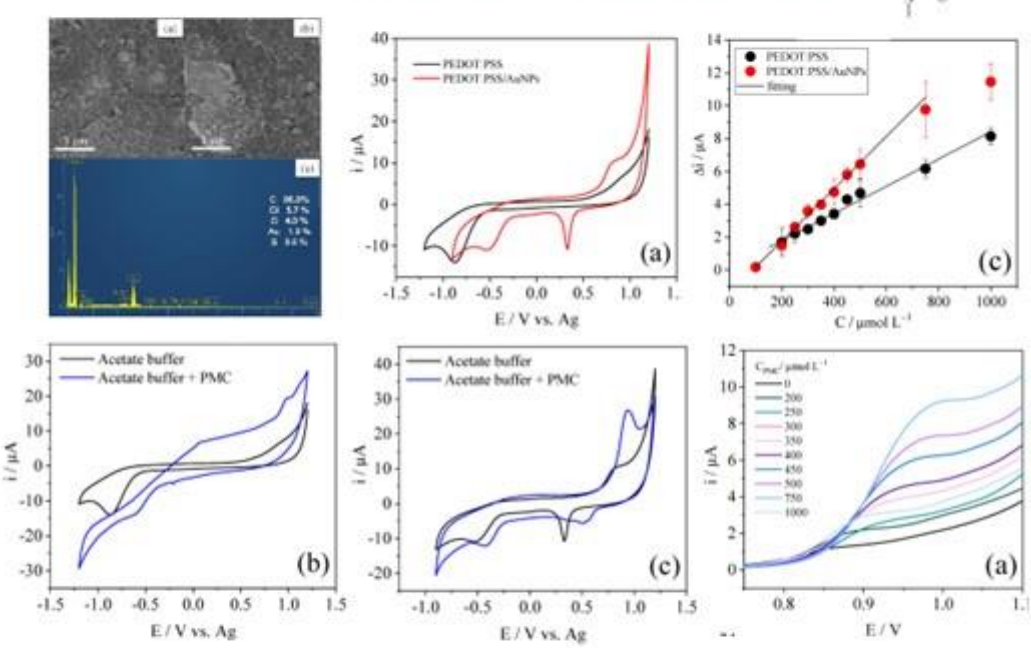
polymers MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

PEDOT: PSS/AuNPs-Based Composite as Voltammetric Sensor for the Detection of Pirimicarb

by Andrei E. Deller [1,†], Bruna M. Hryniewicz [1,†], Camila Pesqueira [1], Rayta Paim Horta [2], Bruno José Gonçalves da Silva [2], Saddam Weheabby [3], Ammar Al-Hamry [3], Olfa Kanoun [3] and Marcio Vidotti [1,*]

Polymers **2023**, *15*(3), 739; https://doi.org/10.3390/polym15030739





Abstract

An electrochemical sensor for the pesticide Pirimicarb (PMC) has been developed. A screen-printed electrode (SPCE) was used and modified with the conducting polymer poly (3,4-ethylenedioxythiophene) (PEDOT) and gold nanoparticles (AuNPs) to enhance electrochemical proprieties. Electrode characterizations were performed using scattering electron microscopy (SEM) and cyclic voltammetry (CV). With the SPCE/PEDOT:PSS/AuNPs modified electrode, a new peak at 1.0 V appeared in the presence of PMC related to the PMC oxidation. To elucidate the mechanism of PMC oxidation, Gas Chromatography-Mass Spectrometry (GC-MS), where two major peaks were identified, evidencing that the device can both detect and degrade PMC by an electro-oxidation process. Exploring this peak signal, it was possible the sensor development, performing detection from 93.81–750 µmol L^{-1}, limits of quantification (LOQ) and detection (LOD) of 93.91 µmol L^{-1} and 28.34 µmol L^{-1}, respectively. Thus, it was possible to study and optimization of PMC degradation, moreover, to perform detection at low concentrations and with good selectivity against different interferents using a low-cost printed electrode based on graphite modified with conductive polymer and AuNPs.

Keywords: pirimicarb; electrochemical sensor; modified electrode; conductive polymers; composites; PEDOT:PSS

biosensors

MDPI

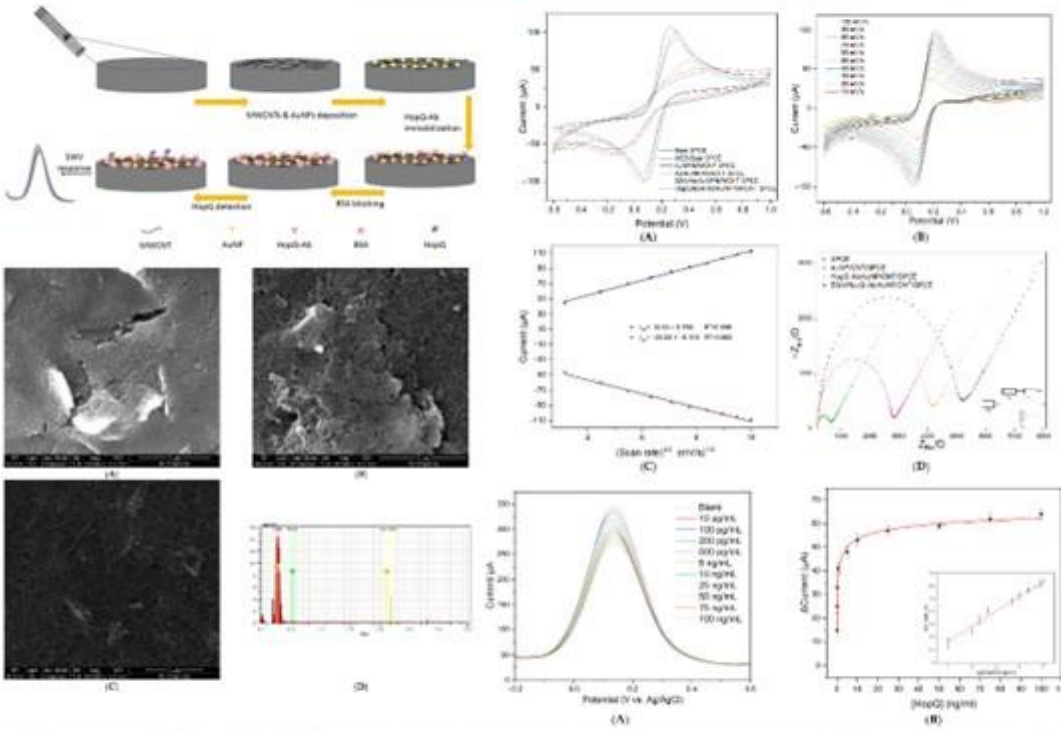
MST
MEASUREMENT AND SENSOR TECHNOLOGY

Article

Novel Sensitive Electrochemical Immunosensor Development for the Selective Detection of HopQ *H. pylori* Bacteria Biomarker

Hussamaldeen Jaradat [1], Ammar Al-Hamry [1], Mohammed Ibbini [2], Najla Fourati [3] and Olfa Kanoun [1,*]

Biosensors **2023**, *13*(5), 527; https://doi.org/10.3390/bios13050527



Helicobacter pylori (*H. pylori*) is a highly contagious pathogenic bacterium that can cause gastrointestinal ulcers and may gradually lead to gastric cancer. *H. pylori* expresses the outer membrane HopQ protein at the earliest stages of infection. Therefore, HopQ is a highly reliable candidate as a biomarker for *H. pylori* detection in saliva samples. In this work, an *H. pylori* immunosensor is based on detecting HopQ as an *H. pylori* biomarker in saliva. The immunosensor was developed by surface modification of screen-printed carbon electrodes (SPCE) with MWCNT-COOH decorated with gold nanoparticles (AuNP) followed by HopQ capture antibody grafting on SPCE/MWCNT/AuNP surface using EDC/S-NHS chemistry. The sensor performance was investigated utilizing various methods, such as cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and scanning electron microscope (SEM) coupled with energy-dispersive X-ray spectroscopy (EDX). *H. pylori* detection performance in spiked saliva samples was evaluated by square wave voltammetry (SWV). The sensor is suitable for HopQ detection with excellent sensitivity and linearity in the 10 pg/mL–100 ng/mL range, with a 2.0 pg/mL limit of detection (LOD) and an 8.6 pg/mL limit of quantification (LOQ). The sensor was tested in saliva at 10 ng/mL, and recovery of 107.6% was obtained by SWV. From Hill's model, the dissociation constant Kd for HopQ/HopQ antibody interaction is estimated to be 4.60×10^{-10} mg/mL. The fabricated platform shows high selectivity, good stability, reproducibility, and cost-effectiveness for *H. pylori* early detection due to the proper choice of biomarker, the nanocomposite material utilization to boost the SPCE electrical performance, and the intrinsic selectivity of the antibody–antigen approach. Additionally, we provide insight into possible future aspects that researchers are recommended to focus on.

Keywords: immunosensor; *H. pylori*; HopQ; saliva; biosensor; nanotechnology; CNT; biomedical engineering

Microchemical JOURNAL

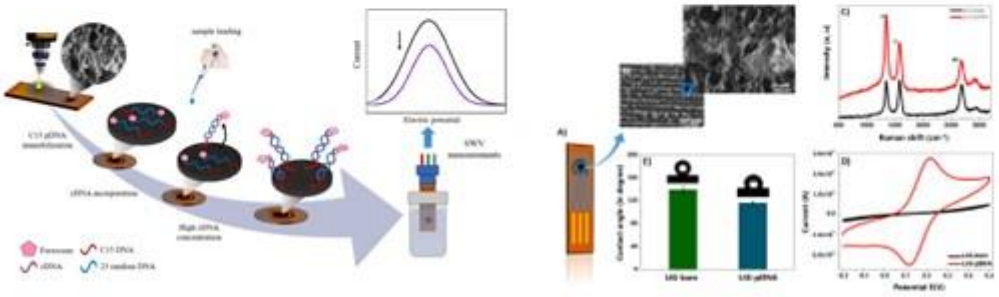
ELSEVIER

MST MEASUREMENT AND SENSOR TECHNOLOGY

Laser-Induced graphene electrodes for highly sensitive detection of DNA hybridization via consecutive cytosines (polyC)-DNA-based electrochemical biosensors

Mohamed Bahri [a,b,c], Mohamed Amin Elaguech [c,d], Salem Nasraoui [e], Khouloud Djebbi [c,d], Olfa Kanoun [e], Peiwu Qin [a,b], Chaker Tlili [c,*], Deqiang Wang [c,d,*]

Microchemical Journal 185 (2023) 108208; https://doi.org/10.1016/j.microc.2022.108208



ABSTRACT

Numerous carbon-based biosensors issued mechanical exfoliation, epitaxial growth, reduced graphene oxide, and chemical vapor deposition have been investigated for highly sensitive and specific detection of DNA. As a promising route for designing electrochemical biosensor-based flexible substrates, the laser-induced graphene technique, which provides a cheap, technologically simple, and highly robust sensing platform, has been widely adopted. However, DNA-based biosensors' efficiency is strongly dependent on how DNA probes are tethered to the nanomaterials. In view of this, poly-cytosine (poly-C) DNA has shown outstanding adsorption to multiple inorganic nanomaterials, including gold (Au), zinc oxide (ZnO), tungsten disulfide (WS_2), graphene oxide (GO), and graphene. In this work, a poly C(15)-tailed diblock DNA probe is used to anchor to carbonized working electrode issued laser-induced method. Meanwhile, the second block modified with ferrocene (Fc) derivatives is lifted at the surface for DNA sequence recognition. Following this strategy, the developed biosensor leads to a limit of detection (LOD) of 57 fM, which was superior or comparable to some previously reported methods. Moreover, the proposed electrochemical DNA biosensor exhibits high specificity in differentiating the complementary DNA from non-complementary DNA (ncDNA), and mismatched DNAs (MM-DNA) sequences. Finally, the easily constructed laser-induced graphene electrode biosensor showed an ability to detect DNA in human serum as a complex environment, making our approach a promising avenue for disease diagnosis.

Keywords:
Laser-induced graphene
DNA immobilization
DNA biosensor
Electrochemical detection

Microchemical JOURNAL

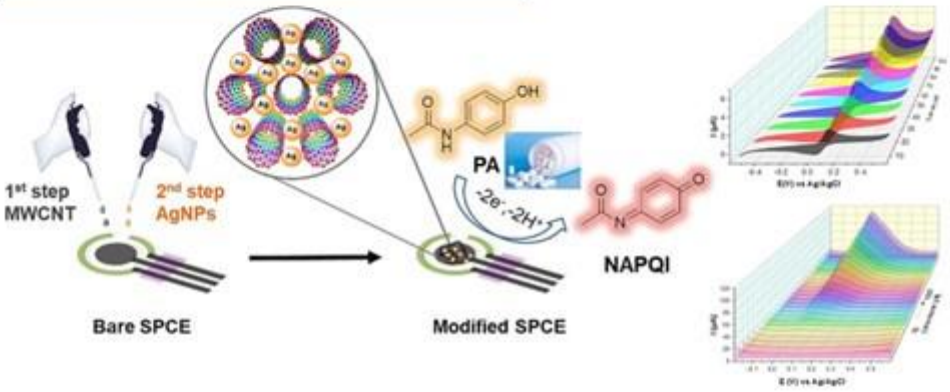
ELSEVIER

MST MEASUREMENT AND SENSOR TECHNOLOGY

Paracetamol detection in environmental and pharmaceutical samples using multi-walled carbon nanotubes decorated with silver nanoparticles

Saddam Weheabby [a], Zhenyn Wu [a], Ammar Al-Hamry [a], Igor A. Pašti [b], Adiraju Anurag [a], Doreen Dentel [c], Christoph Tegenkamp [c], Olfa Kanoun [a]

Microchemical Journal 185 (2023), Vol. 193, 109192,
https://doi.org/10.1016/j.microc.2023.109192



ABSTRACT

Paracetamol (PA) treats mild to moderate pain and fever with a high relative safety factor when administered properly. However, PA overuse creates harmful metabolites and serious illnesses. Thus, PA must be continually monitored and measured in environmental, pharmaceutical, and biological samples. In this work, voltammetric sensing of PA using silver nanoparticles (AgNPs) and carboxylated multi-walled carbon nanotubes (AgNPs@HOOC-MWCNT) deposited on screen-printed carbon electrode (SPCE) has been demonstrated. The AgNPs were prepared through a simple reduction method with an average particle size of 46 nm. Both AgNPs and modified electrodes were characterized by ultraviolet–visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy, scanning electron microscopy, and energy-dispersive X-ray analysis. The electrochemical behaviour of PA over the modified (AgNPs@HOOC-MWCNT@SPCE) was studied using cyclic voltammetry (CV). It has been demonstrated that a relatively small quantity of AgNPs results in a considerable improvement in the active surface area of the modified electrode and an increase in the oxidation current of PA. In addition, a computational study was performed to complement the experimental work. Using square wave voltammetry (SWV) under optimal conditions (pH 7.4 and 25 °C), AgNPs@HOOC-MWCNT@SPCE sensor shows an effective sensing potential with a limit of detection of 0.24 μM in the concentration range of 0.5 to 1000 μM. The reproducibility and repeatability studies and long-term stability for 60 days were illustrated. Ultimately, the practical applications of the proposed method for determining PA in environmental and pharmaceutical samples were demonstrated with satisfactory results.

Keywords:
Silver nanoparticles
Multi-walled carbon nanotubes
Electrochemical sensors
Paracetamol

6 Smart Wearables

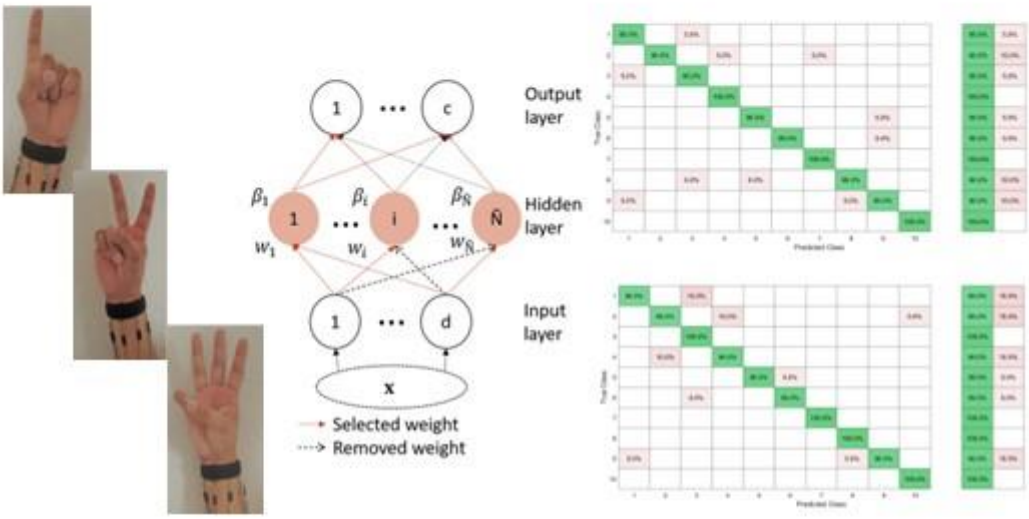
sensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

Open Access Article

k-Tournament Grasshopper Extreme Learner for FMG-Based Gesture Recognition

by Rim Barioul * and Olfa Kanoun

Sensors **2023**, *23*(3), 1096; https://doi.org/10.3390/s23031096



Abstract

The recognition of hand signs is essential for several applications. Due to the variation of possible signals and the complexity of sensor-based systems for hand gesture recognition, a new artificial neural network algorithm providing high accuracy with a reduced architecture and automatic feature selection is needed. In this paper, a novel classification method based on an extreme learning machine (ELM), supported by an improved grasshopper optimization algorithm (GOA) as a core for a weight-pruning process, is proposed. The k-tournament grasshopper optimization algorithm was implemented to select and prune the ELM weights resulting in the proposed k-tournament grasshopper extreme learner (KTGEL) classifier. Myographic methods, such as force myography (FMG), deliver interesting signals that can build the basis for hand sign recognition. FMG was investigated to limit the number of sensors at suitable positions and provide adequate signal processing algorithms for perspective implementation in wearable embedded systems. Based on the proposed KTGEL, the number of sensors and the effect of the number of subjects was investigated in the first stage. It was shown that by increasing the number of subjects participating in the data collection, eight was the minimal number of sensors needed to result in acceptable sign recognition performance. Moreover, implemented with 3000 hidden nodes, after the feature selection wrapper, the ELM had both a microaverage precision and a microaverage sensitivity of 97% for the recognition of a set of gestures, including a middle ambiguity level. The KTGEL reduced the hidden nodes to only 1000, reaching the same total sensitivity with a reduced total precision of only 1% without needing an additional feature selection method.

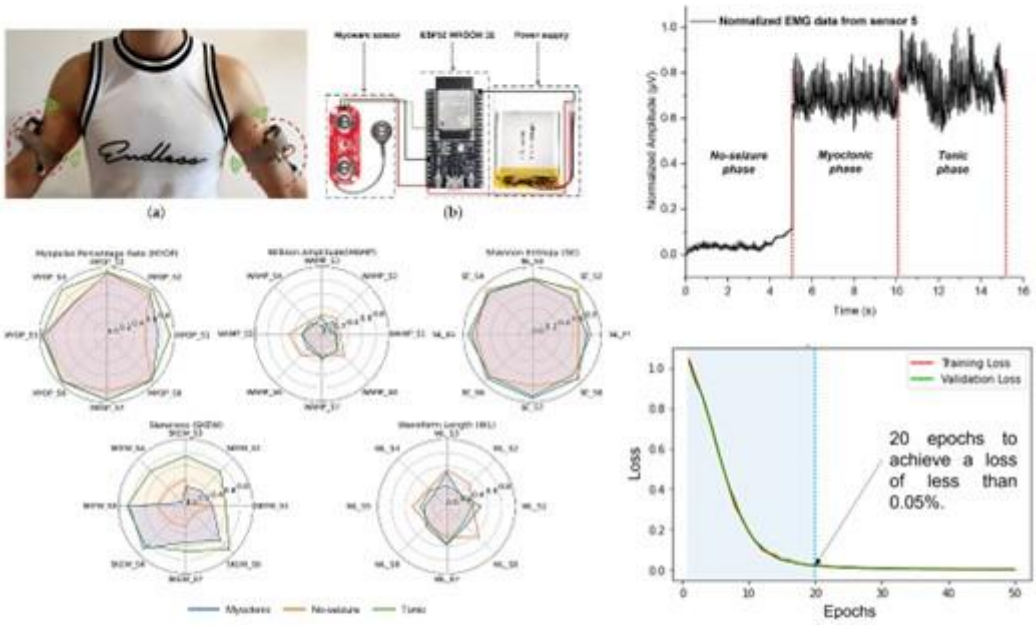
Keywords: extreme learning machine; force myography; grasshopper optimization algorithm; k-tournament selection

sensors MDPI MST MEASUREMENT AND SENSOR TECHNOLOGY

Wearable Electromyography Classification of Epileptic Seizures: A Feasibility Study

by Achraf Djemal [1,2], Dhouha Bouchaala [3], Ahmed Fakhfakh [2] and Olfa Kanoun [1,*]

Bioengineering **2023**, *10*(6), 703; https://doi.org/10.3390/bioengineering10060703



Abstract

Accurate diagnosis and classification of epileptic seizures can greatly support patient treatments. As many epileptic seizures are convulsive and have a motor component, the analysis of muscle activity can provide valuable information for seizure classification. Therefore, this paper present a feasibility study conducted on healthy volunteers, focusing on tracking epileptic seizures movements using surface electromyography signals (sEMG) measured on human limb muscles. For the experimental studies, first, compact wireless sensor nodes were developed for real-time measurement of sEMG on the gastrocnemius, flexor carpi ulnaris, biceps brachii, and quadriceps muscles on the right side and the left side. For the classification of the seizure, a machine learning model has been elaborated. The 16 common sEMG time-domain features were first extracted and examined with respect to discrimination and redundancy. This allowed the features to be classified into irrelevant features, important features, and redundant features. Redundant features were examined with the Big-O notation method and with the average execution time method to select the feature that leads to lower complexity and reduced processing time. The finally selected six features were explored using different machine learning classifiers to compare the resulting classification accuracy. The results show that the artificial neural network (ANN) model with the six features: IEMG, WAMP, MYOP, SE, SKEW, and WL, had the highest classification accuracy (99.95%). A further study confirms that all the chosen eight sensors are necessary to reach this high classification accuracy.

Keywords: epilepsy diagnosis; seizures classification; machine learning; features extraction; features selection; surface electromyography (sEMG); Big-O notation; wearable systems

Professorship Measurement and Sensor Technology
Prof. Dr.-Ing. Olfa Kanoun
Reichenhainerstrasse 70
09126 Chemnitz
https://www.tu-chemnitz.de/etit/messtech/