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Professor Zdravko Stoynov- The Scientist Who Created New Horizons (16.05.1936 – 09.09.2017)

D. Vladikova

Acad. E. Budevski Institute of Electrochemistry and Energy Systems- Bulgarian Academy of Sciences, 10 Acad. G. Bonchev Str., Sofia1113, Bulgaria

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Prof. Zdravko Stoynov left our world abruptly – engulfed in the ebullience of his latest series of advanced inventions. However, he left us an abundant heritage – his spirit, his interminable wonder and inquisitiveness, his developments and inventions – all that he has taught us and brought us up with. It has no dimension, but rather a unique value and it is our duty to preserve, cherish, and augment it.

An original and non-standard personality with the spirit of a gentleman, he turned all that he touched into a masterpiece. His innovative thinking often made him feel as a scientific hermit. Some of his developments were highly evaluated only 10-15 years after their invention, while others are still waiting to be accepted and implemented.

At the age of 24, Zdravko Stoynov built the first in Bulgaria analog computer to calculate differential equations to the 12th order after the decimal point. For over half a century right until his passing, he continued to create and develop algorithms & solutions, which he integrated into his nonstandard equipment, so he could unveil new key phenomena in the electrochemical power sources – the primary zone of his professional interest.

Prof. Stoynov's scientific achievements are not only numerous and significant, but also cross between different disciplines to redefine problems outside normal boundaries and reach solutions based on a new understanding of complex processes - a novel approach in modern science which usually involves different teams of scientists from diverse backgrounds and fields. Zdravko Stoynov's research married electrochemistry with engineering, mathematics, computer sciences… he suited the equipment he created to his experimental goals – from the development of unique hardware and software to original methods for data analysis. For example, he measured the underpotential pre-nucleation of Ag on dislocation free surface of single crystal face by constructing an ultra-sensitive potentiostat with a voltage range of 10 mV and sensitive current measurements. His precision equipment and methodology registered impedance on a single dislocation. His extensive inter-disciplinary knowledge and skills reflected in his academic degrees: Ph.D. in engineering (automatization of the experiment) from the Bulgarian Academy of Sciences (BAS), Doctor of Technical Sciences (technical cybernetics) from Zurich Polytechnical University, and Doctor of Chemical Sciences from BAS.

I have been wondering for many years about the source of Prof. Stoynov's limitless scientific curiosity and inexhaustible constructive energy to define new topics and undertake seemingly insoluble problems, transforming them into fertile and attractive research fields. Finally, I believe I have found the answer in the words of the renowned physical chemist Ivan Stransky: "*A scientist must possess the capability to wonder. He has to see voids where others see nothing*." It is as if those words are especially said for Zdravko Stoynov who managed to preserve and develop this childish curiosity and disregard for limits and taboos which, combined with exceptional intelligence and multidisciplinary knowledge accumulated during the years, made him an extraordinary scientist.

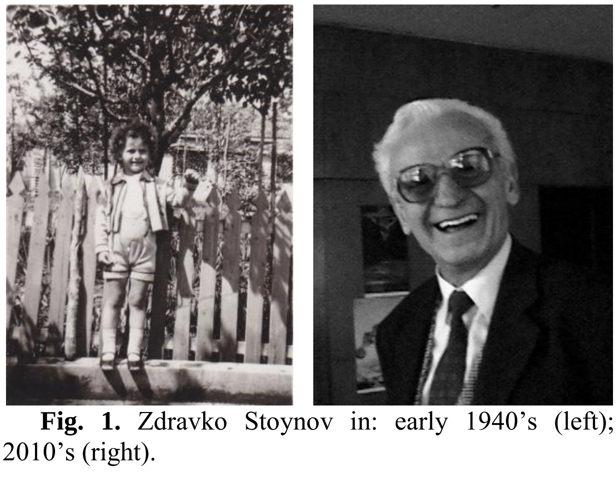


Fig. 1. Zdravko Stoynov in: early 1940's (left); 2010's (right).

To whom all correspondence should be sent:
E-mail: d.vladikova@bas.bg

In 1960, Zdravko Stoynov graduates from the Technical University of Sofia by constructing the first analog computer in Bulgaria. In the next 2 years, he establishes the “Computing and Modeling Laboratory” at the Technical University and constructs a larger analog computer to calculate non-linear differential equations up to the 120th order [1]. At the same time, he is developing non-standard equipment for researchers at the Bulgarian Academy of Sciences. As a result, in 1963 he is introduced to Evgeni Budevski, who is feverishly working with his team on growing a dislocation-free crystal. If successful, they will create the first “perfect crystal” in the world and confirm the Stransky-Kaischew theory of two-dimensional nucleation.

Thus, in 1963 Zdravko Stoynov becomes part of a talented world-renowned research team on the verge of a significant discovery. In a matter of months, he considerably increases the sensitivity, precision, and stability of the measuring equipment and albeit coming from a completely different scientific field, starts to participate actively in the scientific work of the department. Zdravko Stoynov himself enthusiastically describes the atmosphere, emotions, and dedication of the entire team during those exiting times in a contribution for Academician Evgeni Budevski [2]. In 1965, thirty-three years after the publication of the Stransky-Kaischew theory, comes its experimental proof – the Budevski team successfully grows the first in the world dislocation-free single crystal. This accomplishment sparks extensive research of electrochemical performance in a new, experimentally unexplored system with completely different behavior from systems with dislocations in the crystal lattice. Zdravko Stoynov is in the heart of this research, developing models for surface diffusion and monoatomic layer growth [3,4].

With such a strong scientific beginning, what to do next?! His exceptional engineering and mathematical background gives him the unique independence to develop targeted task-specific equipment. From then on, he has freedom to choose what scientific peak to overcome next. He selects a difficult and little exploited at the time, yet exciting field full of potential and enormous opportunities – electrochemical impedance spectroscopy (EIS). In parallel, he continues to work in a pure engineering field, automation of the scientific experiment, developing a series of automated battery testing equipment for the newly established Central Laboratory of Electrochemical Power Sources with Director Evgeni Budevski, founded in 1967 (Figs. 2,3).

Fig. 2. The Electrochemical Methods Department, founded by Zdravko Stoynov: 1986 (up); 2016 (middle and and down).

That equipment is implemented in the Bulgarian lead acid battery plants in Dobrich, Targovishte, and Pazardjik. Prof. Stoynov’s power potentiostats are introduced in the laboratories of the German and Czech Academies of Sciences. During his specialization in Case Western Reserve University in Cleveland, he develops a new generation ultra-fast power potentiostat (BC 6000), which is put into production in Stonehard Ass. (USA) – the company owned by the inventor of the fuel cell for the American lunar rover.

Zdravko Stoynov never ceases to develop unique non-standard equipment (Figs. 3-5), but it serves as a means to a greater end as the focus of his work shifts to experimental methodologies.

Despite his interest and work in various scientific fields, his greatest and undying love remains electrochemical impedance. He is irresistibly drawn to this method by its exceptional informative capabilities and numerous exciting challenges. Electrochemical impedance has the unique advantage of separating the kinetics of the different steps describing the phenomenon or process under investigation. However, there are serious hurdles in the analysis of the experimental data, which need a statistical approach. The challenge is two-fold as both the method and the system under investigation must be considered… and Zdravko Stoynov has been "digging" in both directions… for more than 50 years.

Nowadays, measuring electrochemical impedance with frequency response analyzers is a mainstream method used by all. However, few know that Zdravko Stoynov implements this equipment into electrochemical measurements after a visit to the Solartron company in 1968. The same year the first two frequency response analyzers are bought and introduced by Prof. Epelboin in his laboratory in Paris (CNRS-UPMC, Université Pierre et Marie Curie) and by Zdravko Stoynov in CLEPS (Bulgarian Academy of Sciences).

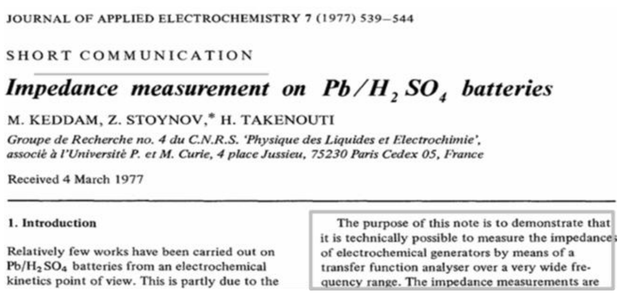
Working in a "battery institute", Zdravko Stoynov decides to investigate the impedance of batteries – an object whose impedance is considered impossible to measure at the time. Under these circumstances, he starts to systematically chisel away at the scientific taboos… and continues to do so till his last day.

Fig. 3. Zdravko Stoynov's computerized testing laboratory in CLEPS (1975).

Fig. 4. Zdravko Stoynov's "Hydrogen Laboratory" in IEES (2015).

Fig. 5. Zdravko Stoynov and Massimo Schiavetti in front of Stoynov's equipment for impedance testing of large batteries for accumulation of energy from solar cells (ENEL- Pisa, 2014).

For a start, he introduces measurements outside the point of chemical equilibrium. Today, this is customary. However, it is completely unheard of nearly 40 years ago. Prof. Stoynov develops specialized equipment and with his colleagues at CNRS in Paris measures, for the first time in the world, impedance of batteries – galvanostatically and quasistrationary [5] (Fig. 6). A year later, he measures the impedance of large-scale batteries and promotes the introduction of this method in laboratories and practices of the European Space Agency, the Soviet space program, as well as in the Lewis Center at NASA.



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SHORT COMMUNICATION

Impedance measurement on Pb/H_2SO_4 batteries

M. KEDDAM, Z. STOYNOV,* H. TAKENOUTI

Groupe de Recherche no. 4 du C.N.R.S. 'Physique des Liquides et Electrochimie', associé à l'Université P. et M. Curie, 4 place Jussieu, 75230 Paris Cedex 05, France

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1. Introduction

Relatively few works have been carried out on Pb/H_2SO_4 batteries from an electrochemical kinetics point of view. This is partly due to the

The purpose of this note is to demonstrate that it is technically possible to measure the impedance of electrochemical generators by means of a transfer function analyser over a very wide frequency range. The impedance measurements are

Fig. 6. The first publication for impedance on batteries.

Delving deeper into the subject, Prof. Stoynov focuses on the non-steady state of batteries during the impedance measurement process.

Non-stationary (4-D) impedance analysis

Based on the classical method of the Transfer Function (TF), Electrochemical Impedance Spectroscopy gives a local, linearized and full (in a frequency aspect) description of the investigated electrochemical system, which is assumed to be a steady-state one. However, batteries behave as big statistical systems with distributed parameters on a macro and micro scale. During cycling, processes of mass and energy transfer take place. They change the object's structure and parameters. Thus, batteries show non-steady state behavior, which is a restriction for correct impedance studies. For further development of the impedance of batteries, a liberation from the restriction of steady state conditions is needed and thus Zdravko Stoynov develops non-stationary (4-D) impedance analysis – a procedure which eliminates delay errors [6-9].

This approach is based on the assumption that the state and the parameter space of the system is a continuum. It corrects the errors arising from the measurement delay during the frequency sweep. In contrast to classical electrochemical impedance spectroscopy, which works with a 3-dimensional (3D) set of data, Zdravko Stoynov formulates a 4-dimensional initial set of experimental data, including the time of measurement. He approximates every iso-frequency dependence with a formal model and applies two orthogonal iso-frequency cubic splines respectively for the real and the imaginary components. The interpolation (and extrapolation) for a given time t_j and a set of frequencies ω_i gives the corresponding estimates of the real and imaginary parts. Thus, the data of each evolving diagram are reconstructed and the corresponding impedance diagrams already represent the impedances measured virtually at the same time for all frequencies. This, in practice, corrects the deformations due to the non-steady state evolution (Fig. 7).

Stoynov's innovative 4-D approach improves significantly the impedance studies of batteries [10-13]. It is no wonder this method has been introduced in the battery testing software of Zahner Elektrik GmbH & Co. KG and successfully applied by Mitsubishi in Li-ion battery research [14, 15], as well as for studies of other time-evolving systems [16, 17].

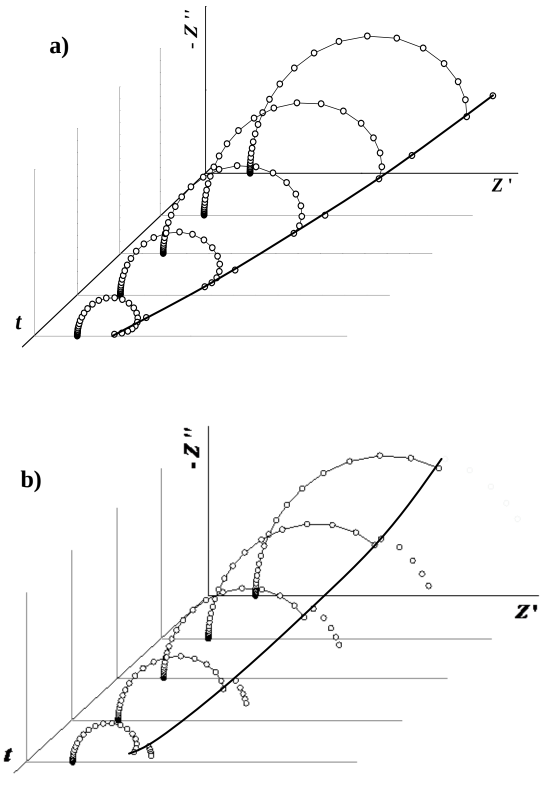

Fig. 7. Simulated impedance diagrams of an evolving simple Faradaic reaction deformed by measurement delay errors: a) iso-frequency dependence for the lowest frequency; b) fifth iso-frequency dependence (starting from the lowest frequency). *Reproduced with permission from D. Vladikova (2006) Nonstationary differential impedance spectroscopy in energy sources. In: Stoynov Z. and Vladikova D. (eds.) Portable and Emergency Energy Sources, pp. 411–436. Sofia: Marin Drinov Academic Publishing House.*

Rotating Fourier Transform (RFT)

The non-steady state conditions of the electrochemical system during impedance measurements penetrate deeper, affecting the Fourier Transform (FT), which is the mathematical kernel of every impedance analyzer of our days. The FT is the best estimator of sinusoidal signals in steady-state conditions. However, out of those conditions, the FT produces specific errors dependent on the frequency. After a profound analysis of those errors, Zdravko Stoynov succeeds to develop theoretically an advanced generalized form of this transform – the Rotating Fourier Transform. This is the subject of his doctoral dissertation in the Federal Institute of Technology – Zurich [18, 19]. The implementation of the RFT in impedance spectroscopy provides for precise measurements of time-evolving systems out of steady-state conditions. It opens a new horizon for studies of batteries and fuel cells, corrosion and numerous other systems.

During the last year of his life, Zdravko Stoynov refocuses on further theoretical and experimental development of his advanced mathematical RFT tool, introduced 30 years ago. He describes it as a “powerful engine for non-stationary impedance spectroscopy which opens up the exploration of the low and infra-low frequencies where many important and interesting phenomena, still hidden, can be measured precisely”. Expecting the development of new “4th Generation” marketable impedance analyzers through the application RFT and MRFT (Multiple RFT) in the near future, he labors over both the mathematical tool and his experimental verification (Fig. 8) in order to accelerate the coming of this "near future" and to be able to see it (Fig. 9). An unedited version of his last unpublished work on this topic, written months before his passing, is presented in this issue in “Letters to the Editor” [20].

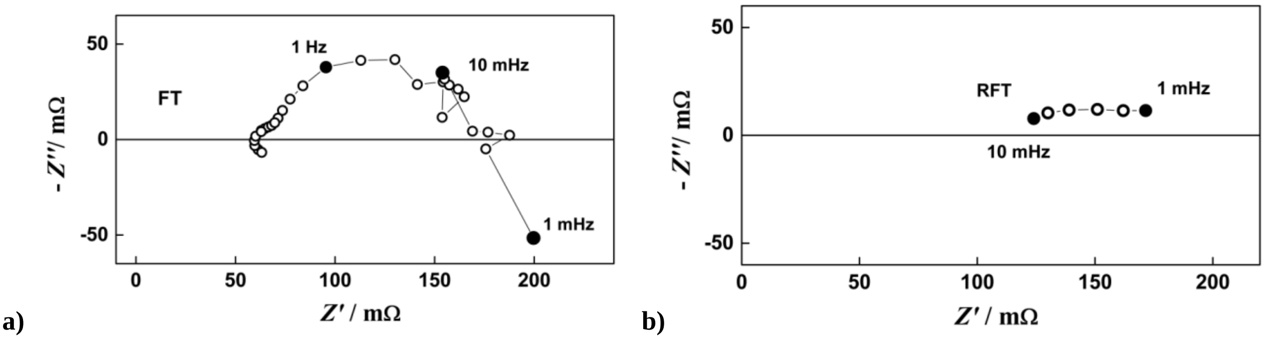

Fig. 8. Impedance diagrams of Li-ion battery 2000 mAh during charge with 100 mA: (a) produced by conventional Impedance Analyzer (Solartron 1260) using Fourier Transform. Frequency range 1 kHz – 1 mHz, 5 points/decade, A.C. current amplitude 11 mA; (b) produced by Rotating Fourier Transform of the data from Fig. 8a. Frequency range 10 mHz to 1 mHz, 5 points/decade [20].

Fig. 9. Bio-logic Science Instruments (Grenoble 2017): Zdravko Stoynov is explaining visually his Rotating Fourier Transforms.

Differential Coulometry Spectroscopy

Battery testing is an important application-oriented tool for evaluation of their operational capability and performance as sources of energy and power. The typical testing results give general information that represents the overall behavior and thus does not support the analytical understanding of the processes taking place. To fill this gap, Zdravko Stoynov develops Differential Coulometry Spectroscopy (DCS), which extracts valuable information about the batteries' internal kinetics, electrochemical design, and life degradation. This technique requires measurements of the voltage changes in time followed by precise aperiodic function Spectral Transform Analysis [21]. In order to separate the thermodynamic kinetics from the masking dynamic effect of the intrinsically connected transport limitations, very slow-rate galvanostatic testing (charge/discharge) is required. In principle, the galvanostatic mode of testing is a sweep coulometry and provides for the evaluation of the quantity of electricity necessary for the propagation of the investigated process or its steps. DCS has been found to be a useful tool for investigating the electrochemical behavior and performance of rechargeable batteries based on intercalation materials (Fig. 10). Recently, it has been included in the analysis package of BioLogic Science Instruments' EC-Lab software version V11.01 [22].

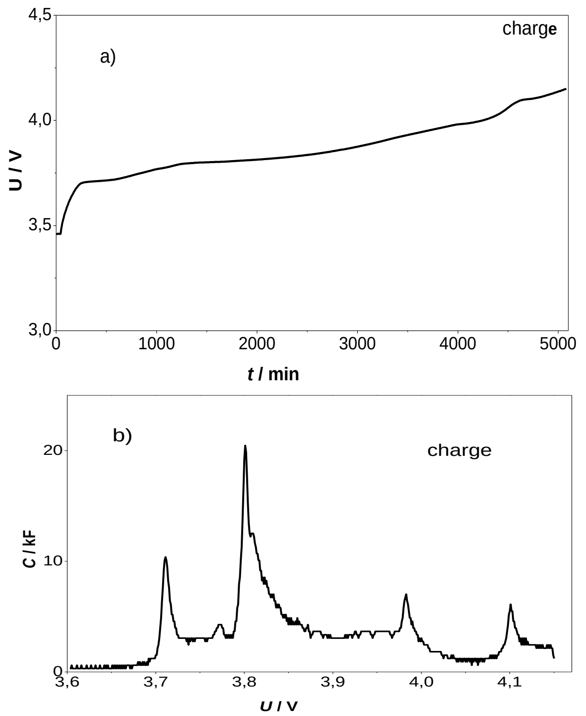

Fig. 10. Four volts Li-ion sample with nominal capacity of 2200 mAh: (a) Slow sweep voltage–time charge curve (h = 100 hours); (b) Capacity spectrum of the slow sweep voltage–time charge and discharge curves (h = 100 hours). *Reproduced with permission from D. Vladikova (2006) Differential Coulometry spectroscopy in: Stoynov Z. and Vladikova D. (eds.) Portable and Emergency Energy Sources, pp. 437–449. Sofia: Marin Drinov Academic Publishing House.*

Differential Impedance Analysis (DIA)

Although electrochemical impedance as a TF gives a local, linear, and full description of the system under study, this information must be extracted from the experimental data, since impedance does not directly measure the processes caused by the perturbation signal, i.e. it is not a physical reality, but an information property of the object. The commonly applied approach for the interpretation of the experimental data is the construction and confirmation of a preliminarily derived hypothetical model. The model structure is chosen *a priori*, and thus the identification procedure is only parametric.

The main efforts towards the improvement of the impedance data analysis are focused on the advancement of the identification procedure. In this direction, Zdravko Stoynov's achievements start with the development of the original Model Reduction Method [23]. However, the data analysis advancements by improvements in the parametric identification do not satisfy him because of the principle discrepancy between the power of the impedance measurement technique, which ensures a large volume of precise data, and their analysis, based on the formulation of hypotheses, often built on subjective or oversimplified assumptions.

In Technical Cybernetics, the Structural Identification Approach is applied for data analysis. It does not require an initial working hypothesis and provides both structural and parametric identification. However, the application of this procedure to electrochemistry creates a multitude of problems for a long time accepted as insoluble. This challenge attracts Zdravko Stoynov and to overcome it, he develops the technique of Differential Impedance Analysis (DIA), introducing the Structural Identification approach in the frequency domain [24-30] – one of his biggest breakthroughs and a monument to out-of-the-box thinking.

The DIA procedure starts with the initial set of experimental data (angular frequency, real and imaginary components of the impedance), and thus can be applied to previously measured data. The kernel is the local scanning analysis, performed with the so-called local operating model (LOM) with a simple structure consisting of a resistance R_1 in series with a parallel connection of capacitance C and a second resistance R_2. The effective time-constant $T = RC$ is also introduced as a LOM parameter. In contrast to the classical parametric identification performed over the entire frequency range, which estimates the parameters' vector as a preliminary chosen model structure, the identification of the LOM parameters' vector by local analysis is carried out within a narrow frequency range, regarded as an operating window. When the window width is a single frequency point, the solution is purely deterministic. The following steps describe the procedure of the structural and parametric identification:

- Scanning with the LOM throughout the whole frequency range with a scanning window of a single frequency point;
- Parametric identification of the LOM at every

working frequency. Since the number of the independent data available inside the observation window is smaller than the number of the unknown parameters, the initial set of impedance data is extended with two additional terms – the derivatives of the real and imaginary components of the impedance with respect to the frequency. Thus, the set of equations determining the LOM parameters estimation becomes solvable;

- Frequency analysis of the LOM parameters' estimates. The results are presented in the so-called temporal plots, which give the frequency dependence of the LOM parameters' estimates (Fig.11). If the LOM parameters' estimates are frequency-independent in a given frequency region, the sub-model corresponding to this frequency segment follows the LOM structure, i.e. it is described with a parallel combination of capacitance and resistance, which determine a time-constant. Thus, the number of the plateaus gives the number of the time-constants in the model (Fig. 11b). The results can be transformed in spectra, where the plateaus are depicted as spectral lines (Fig. 11c, d) [27-30].

The presence of frequency dependence in the temporal plots marks either the regions of mixing between two phenomena, or frequency-dependent behavior. Those segments are additionally examined by Secondary DIA [27, 29, 30]. The procedure, known as differential temporal analysis, includes the differentiation of the LOM parameters' estimates with respect to the log frequency. It recognizes frequency-dependent elements (CPE, Warburg, Bounded Warburg etc.) as well as their presence in more complicated models. DIA opens new horizons for EIS by increasing its information capability. It is successfully applied in electrochemical power source studies and other systems [30-40].

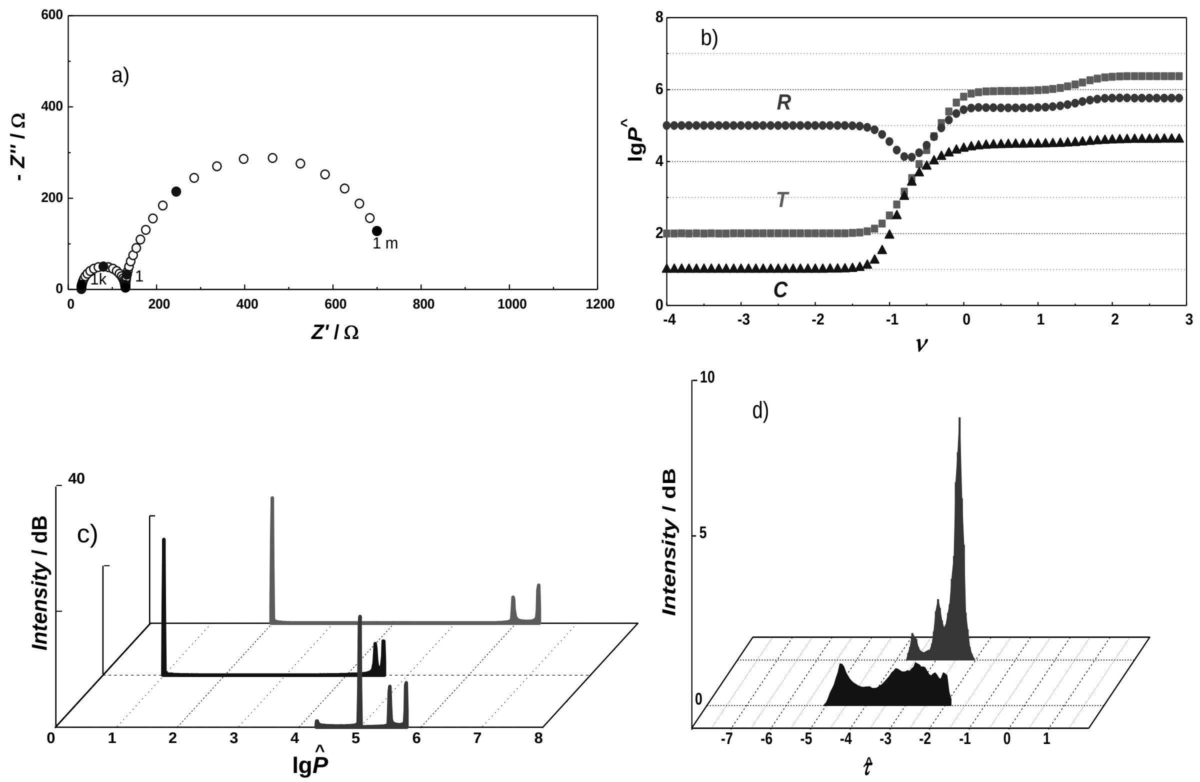

Fig. 11. DIA of a three-step reaction: (a) equivalent circuit and complex-plane impedance diagram; (b) temporal plots (c) spectral plots; d) time-constant spectra of motor oil Mobil Delvac MX 15W40: new (■); after 10000 km. (■). *Reproduced with permission from D. Vladikova (2005) Differential Impedance Analysis. Sofia: Marin Drinov Academic Publishing House.*

Differential Resistance Analysis

Zdravko Stoynov's final invention, developed in the last months of his life, is related to the most severe hurdles facing the deployment of batteries and fuel cells – lifetime and durability, and more precisely – their reliable evaluation. The SoA degradation already requires long-term testing, which can take several years – a huge deterrent to market deployment. For the moment, the problem-solving approach consists in the development of accelerated stress test (AST) procedures and protocols, which should shorten the testing time in conditions activating the same aging mechanisms as non-accelerated testing. This is a critical moment, since the measured degradation should be transferred to the real-life behavior of the tested system. Thus, the selection of the acceleration parameters and the level of acceleration are of critical importance and may differ significantly between systems and applications.

The latest invention of Zdravko Stoynov offers a new and original approach that decreases the testing time by increasing the sensitivity and accuracy of the standard monitoring and diagnostic tools, providing reliable quantitative information. The new Differential Analysis of the current-voltage characteristics (DIVA) surprises with its simplicity and originality [41-43]. It works with Differential Resistance (dR), i.e. with the derivative of the voltage with respect to the current, which is more sensitive to small deviations and thus ensures increased sensitivity (Fig. 12). The introduction of a spectral transformation procedure additionally increases the noise immunity and sensitivity of the method (Fig. 13) [41-43].

The Differential Resistance Analysis (DRA) introduces new performance indicators and can give information about the origin of the degrading phenomena via a combination with impedance measurements in selected characteristic working points. The analysis is about 10 times more sensitive than the classical evaluation of degradation based on voltage decrease measurements at constant current.

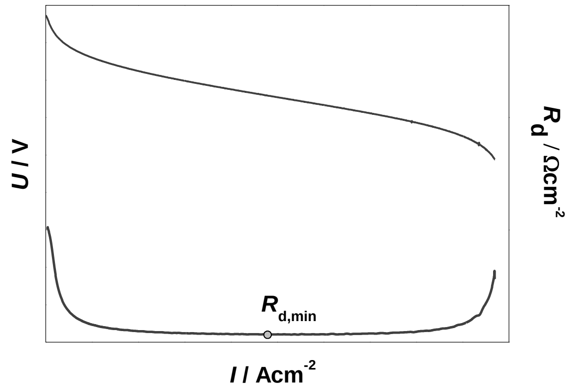

Fig. 12. DiVA procedure: i-V curve and R_d/I dependence.

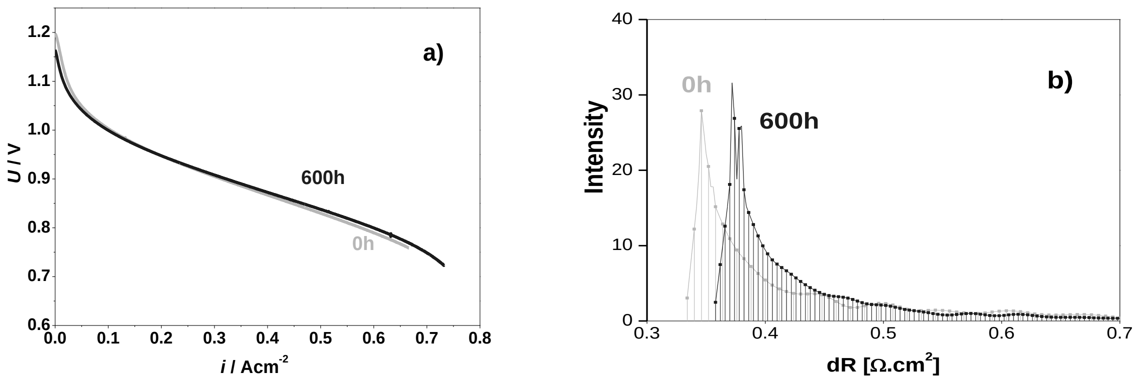

Fig. 13. DIVA of SOFC: (a) *I-V* curves measured during 600 hours testing; (b) spectral transform of the Differential Resistance dR = d*U*/d*I*).

International Activities

Although engulfed in practical and applied research, Zdravko Stoynov is no less valued as a "social scientist" with an acute sense of establishment, with excellent teaching skills, and with an unwithering enthusiasm to educate and pass on his knowledge and skills. He is one of founders of the international impedance society, a similarly minded enthusiastic group of colleagues fascinated by the potential of electrochemical impedance. For over 30 years, it has been gathering within the framework of two international conference chains:

• The International Electrochemical Impedance Spectroscopy Symposia (EIS), dating from 1989 (Fig. 14);

• The International Electrochemical Impedance Analysis Symposia (EIA), dating from 1988 (organized in Bulgaria in 1991, 1994, 2014) (Fig. 15).

On a regional level, he is one of the driving forces behind the establishment of the Regional Symposium of Electrochemistry – South-East Europe (RSE-SEE) and acts as its co-organizer in 2015 (Fig. 16). Starting in 1996, Zdravko Stoynov also establishes the national electrochemical event with international participation “Sofia Electro chemical Days” (Fig. 17).

Till his last day, Prof. Stoynov continued to invigorate these scientific forums with his innovative and avant-garde ideas.

Taking full advantage of and further developing the opportunities of virtual communication and dissemination tools, in 2002 he establishes the European Internet Center for Impedance Spectroscopy with its e-school, e-seminars and free-access e-journal (Impedance Contributions Online) – an extremely avant-garde idea for the first years of the 21st Century. For the past 16 years, the Proceedings of the EIA Symposium have been published in Impedance Contributions Online. In fact, Zdravko Stoynov was preparing to give the introductory speech for EIA11, dedicated to the 30th Anniversary of the Symposium, which, fate would have it, he would not attend.

Fig. 14. (a) International Symposium on Electrochemical Impedance Spectroscopy; (b) Official Dinner, Algarve, Portugal, 8th EIS Symposium, 2010; (c) Lecture, A Toxa, Galicia, Spain,,10th EIS Symposium, 2016..

Fig. 15. International Symposium on Electrochemical Impedance Analysis (EIA): (a) Castle Trest, Moravia, Czech Republic, 5th EIA Symposium, 2008; (b) Welcome party, Red Island, Croatia 9th EIA Symposium, 2011; (c) Opening session, Borovetz, Bulgaria, 10th EIA Symposium, 2014.

Fig. 16. 5th Regional Symposium on Electro chemistry - South East Europe (RSE-SEE5), Pravets, Bulgaria, 2015.

Fig. 17. Opening of Sofia Electrochemical Days, 2012.

In the first difficult years after the fall of the iron curtain and the changes in Bulgaria, the Central Laboratory of Electrochemical Power Sources, as well as the Bulgarian Academy of Sciences as a whole, are functioning under the impending doom of being closed down and a great number of researchers leave the country to seek professional realization in Western Europe and the USA. However, during those troubling times, Prof. Stoynov's sense of duty towards Bulgarian science and his remaining colleagues does not permit him to emigrate. Instead of packing his suitcases for California, where he is expected to join the staff at Stanford University, he undertakes the responsibility to preserve and develop the scientific legacy of his greatest teachers Rostislaw Kaischew and Evgeni Budevski, accepting the position of Director of CLEPS in 1992. Four years later, he is elected as Chairman of the General Assembly (GA) of the Bulgarian Academy of Sciences - the executive body expected to reform the Academy in order to preserve its existence.

Prof. Stoynov once again unites seemingly disparate fields such as electrochemistry, management, economics, and policy-making. He applies to management his rich experience from impedance studies of energy systems, which behave as large statistical systems with distributed parameters on a micro and macro scale. He discerns that scientific infrastructure can be viewed as a large statistical system and can thus be analyzed and optimized in a similar way. The tool he offers for this system on a small and large scale (IEES and BAS) is a new type of scientific management based on: (i) microeconomic reforms; (ii) stable project financing; (iii) global scientific market participation; (iv) high-quality and high-level scientific products with a new positive emphasis on applied research, adequately balanced with fundamental studies.

Now, 25 years later, this socio-economic experiment which Prof. Stoynov takes an active leading role in has proven to be successful (Figs. 18,19). Not only has the Central Laboratory of Electrochemical Power Sources grown into the Institute of Electrochemistry and Energy Systems, one of the most successful BAS institutes with strong participation in the European Research Area, but also the Bulgarian Academy of Sciences has withstood the turmoil of the post-communist transition period and strengthened its position as a national research center with a 150-year history and a bright future ahead.

Zdravko Stoynov establishes the Innovation Centre at BAS, which has grown to be a long-term partner in the Enterprise Europe Network. He initializes the establishment of BAS Education Center, through which the Bulgarian Academy of Sciences obtains its accreditation for training and education.

Fig. 18. Celebration of Zdravko Stoynov's 80th Anniversary (16.05.2016): Prof. Stoynov receives the President of BAS Medal (16.05.2016) (1,2); together with the Electrochemical Methods Department team (3); flowers for „The Boss" at the birthday party (4).

Fig. 19. The "Zdravko Stoynov" Award (left) and the awarding ceremony for its first recipient, Antonio Bertei of Pisa University (Italy), during the 11th International Electrochemical Impedance Analysis Symposium (November 2017)

Noting the weakening of the BAS institutes in terms of the most valuable resource of any effective scientific infrastructure - the expert human resource, Prof. Stoynov implements proactive policies for career advancement and maintenance of the scientific staff above critical levels. While such policies sound trivial today, they are almost unheard of in Bulgaria during the 1990's and the beginning of the 21st century.

His advanced thinking gives birth to the original idea for a portable hydrogen refueling station, which with his inherent sense of humor, he calls “the bogie”. It is introduced in 2013 in the National infrastructure proposal for “Energy Storage and Hydrogen Energetics”, coordinated by IEES and accepted as part of the National Roadmap. It is in 2018 that we see for the first time in Bulgaria one of the new portable refueling stations, built by Air Liquide, fueling the demonstration hydrogen vehicles during the Summit for Hydrogen Applications organized for the 10^{th} anniversary of the Fuel Cells and Hydrogen Joint Undertaking. Had the national infrastructure project started in 2014, Prof. Stoynov’s idea would have probably led to Bulgaria demonstrating its own portable refueling station in the event.

It is a quite rewarding experience to be able to reap what you have sown. Zdravko Stoynov could reap the respect and appreciation of his friends and colleagues from IEES, BAS, and all over the world, who joined together physically and virtually to celebrate his 80's birthday, turning it into a joyous and heartwarming event (Figs. 14-18).

The Bulgarian Academy of Sciences honored his exceptional service with the special medal of the President of BAS (Fig. 18), crowning and completing his BAS honors collection. On his anniversary, the international electrochemical community and Bulgarian colleagues expressed their gratitude to Prof. Stoynov for his insightful avant-garde contributions to the development of electrochemical science and its applications with a special issue of Bulgarian Chemical Communications, which included 30 publications by scientists from 13 countries.

As an age-old adage claims, scientists can only see further by standing on the shoulders of Giants. Professor Zdravko Stoynov will be remembered by his contemporaries and the generations that follow him as his colleague and comrade Digby Macdonald from UC Berkley describes him – “a Giant in electrochemical impedance spectroscopy”.

Philosophers say that a man dies only when the memory of him is gone. The memory of Zdravko Stoynov will not fade. It will not be gone. It remains strong within the large international family of his students, colleagues, and friends from all over the world who honor, respect, and appreciate him. They named the Internet Center for Impedance Spectroscopy after him as it he who for 15 years developed and helped it grow into a powerful open platform for both beginners and experts in the field of impedance research. The “Zdravko Stoynov” prize in his honor will be awarded at each meeting of the International Electrochemical Impedance Analysis Symposium to foster and promote creative out-of-the-box thinking in young researchers (Fig. 19). The memory of Zdravko Stoynov is persistent, as are his deeds. All that he has sown and nurtured will continue to bear fruit into the future.

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Здравко Стойнов - Ученият, който създаваше нови хоризонти

Д. Владикова

Институт по електрохимия и енергийни системи „Акад. Евгени Будевски“, Българска академия на науките, ул. Акад. Г. Бончев, бл.10, София 1113, България