

7th CROSS-BORDER SEMINAR ORGANIZED BY CHARLES UNIVERSITY AND UNIVERSITY OF REGENSBURG Hojsova Stráž, April 15 – 17, 2025

This paper is dedicated to the 100th anniversary of the Department of Analytical Chemistry at the Faculty of Science, Charles University

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This article briefly characterizes presentations of PhD students in electroanalytical chemistry at this cross-border seminar organized jointly by Department of Analytical Chemistry, Faculty of Science, Charles University in Prague, and the Institute of Analytical Chemistry, Chemo- and Biosensors, Faculty of Chemistry and Pharmacy, University of Regensburg. On the basis of these presentations, new trends in present electroanalytical chemistry are discussed together with their application in different natural sciences and with their combination with different separation and spectrometric methods.

Keywords: cross-border cooperation, modern electro-analytical methods, electrochemistry in flowing systems, miniaturization in electroanalytical chemistry, capillary electrophoresis and related methods

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1. Introduction

The 7th Cross-Border Seminar on Electroanalytical Chemistry (CBSEC) took place on April 15–17, 2025 in the beautiful surroundings of the Training Centre of the

Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences (CAS) in Hojsova Stráž, Šumava (see Figure 1). At the outset, we would like to thank the sponsors and institutions whose logos are listed in the header of this article and whose material, organizational, and moral support made it possible that this year, the participants of this seminar did not have to pay any conference fee, accommodation, or food. This is becoming a notable exception in these days of increasing commercialisation in the presentation of the results of scientific research, whether in scientific journals or at scientific conferences. Particularly great thanks go to the management of Charles University, whose POINT programme (POdpora INternacionalizace (Support of Internationalization) at Charles University), designed specifically to support extracurricular international events¹, made a significant contribution to the funding of



Fig. 1. Group photo of participants in the 7th CBSEC in front of the Training Centre of the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences (Bečvářův srub) in Hojsova Stráž

this unusual seminar. The same thanks are due to the management of the Faculty of Science of Charles University and in particular to Mgr. Pavla Poušková and Mgr. Kateřina Lapiszová from the Foreign Department of the Faculty of Science, whose willingness, skills, and helpfulness made life easier for the organizers of this seminar. And our further thanks go to Prof. Jan Konvalinka, Director of the Institute of Organic Chemistry and Biochemistry of the CAS, for his support of our seminar and for making it possible to hold it at the Institute's training centre. And of course we must not forget Prof. F.-M. Matysik and other German colleagues from Regensburg, without whom this event could not have taken place at all, and to the Working Group on Electrochemical Methods of Analysis (Elektrochemische Analysenmethoden – ELACH) of the German Chemical Society (GDCh), which financially supported the participation of German PhD students and a wonderful dinner in the Bavarian part of Železná Ruda.

2. Overview and characterization of presented papers

As in previous years (see ref.²), the seminar was intended for PhD students focusing on modern electroanalytical methods (see ref.³). We are pleased to note the increasing number of Czech and German universities and institutions whose PhD students

participated in this seminar. Another positive aspect is the growing range of presented electroanalytical studies covering not only typical and nowadays classical applications of modern electroanalytical methods for the determination of various analytes of interest in different matrices, but also modern analytical methods used in the development and testing of new batteries or in individual elements of the hydrogen economy. This fact is clearly documented by the following list of presented papers and their authors, presented in English, which was of course the official language of this seminar.

1. **Seydehelahe Bagherimetkazini** (Uni Regensburg, DE): Hyphenation of Electrochemistry with Capillary Electrophoresis and Mass Spectrometry.
2. **Michelle Brandao Silva de Assis** (K Schwabe Inst, Meinsberg, DE): Design and Development of a Potentiometric Nitrate Sensor for *In-Situ* Water and Soil Monitoring.
3. **Jan Dismas Buriánek** (Univ Chem Technol, Prague, CZ): Methodology of Evaluating the Activation Energy of Oxygen Reduction Reaction on Pt-Based Electrodes.
4. **Peter Čambal** (Charles Uni, Prague, CZ): Functionalization of BDD Surface by Reductive Electrografting.
5. **Lucie Dostálková** (Heyrovsky Inst, Prague, CZ): The Influence of Functional Groups of Selaginulvilins on Their Oxidation Properties.

6. **Marius Engler** (Tech Uni Ilmenau, DE): *In-Situ* Microgravimetry for the Determination of Deposition Rates and Efficiencies for the Cycling of All-Iron Redox-Flow Batteries.
7. **Lukas Esper** (Tech Uni Ilmenau, DE): Coulometric Analysis of Additively Manufactured Alloys for Electropolishing.
8. **Ján Labuda** (Slovak Tech Uni, Bratislava, SK): Flow-Through Analytical Systems with Electrochemical Detection for Monitoring of Biologically Active Species. (This special presentation was part of dissemination of results of IUPAC Division V (analytical chemistry) project focussed of the use of modern electroanalytical methods in flowing systems for monitoring of biologically active organic compounds (see ref.^{4,5}).
9. **Kristýna Havelková** (Uni Chem Technol, Prague, CZ): Applications of Polymer Films in Forensic Practice.
10. **Sofia Ivakh** (Charles Uni, Prague, CZ): Pilot Study on Modification Strategies to Access Fairly Negative Potential Range on Silver Screen-Printed Electrodes for Salinomycin Voltammetric Sensing.
11. **Martin Jirásko** (Uni Chem Technol, Prague, CZ): Electrochemical Synthesis and Separation of Iodylbenzoic Acid.
12. **Hyesung Kim** (FAU, Erlangen-Nürnberg, DE): Thin Semiconductor Film Deposition by DC Reactive Magnetron Sputtering for Photoelectrochemical and Photocatalytic Applications.
13. **Martin Koall** (Uni Regensburg, DE): Coupling Non-Aqueous Capillary Electrophoresis and Electrochemistry – Concepts for Electrochemical Detection and Mechanistic Investigations.
14. **Karolína Kukralová** (Uni Chem Technol, Prague, CZ): Dual-Mode Electrochemical SERS Detection of PFAS Using Functional Porous Substrate.
15. **Oleksandra Labzová** (Heyrovsky Inst, Prague, CZ): Voltammetric Determination of Antidepressant Drug Trazodone in Biological Samples After a Hollow Fiber-Based Liquid-Phase Microextraction.
16. **Svetlana Pucovski** (Charles Uni, Prague, CZ): Voltammetric Determination of Genotoxic Fluoren-9-one on a Bare and Copper Film Modified Silver Solid Amalgam Electrode.
17. **Shanshan Qin** (FAU, Erlangen-Nürnberg, DE): Ultra-Low Amount of Pt Single Atoms Selectively Loaded on Minor (101) Facet of Anatase Crystallites Enables Outstanding Utilization Efficiency for Photocatalytic H₂ Production.
18. **Jana Rosenkranzová** (Uni Chem Technol, Prague, CZ): Electrochemical Preparation of Mesoporous Au Nanostructures for Multimodal Detection.
19. **Sabrina Schönemeier** (Uni Regensburg, DE): Analysis of Thermal Degradation Products in Lithium-Ion Cell Electrolytes.
20. **Martin Šefčík** (Charles Uni, Prague, CZ): Studying Electrochemical Oxidation of Pharmaceuticals in Wastewater Treatment: Utilization of Custom 3D-Printed Cell.
21. **Patrik Švejda** (Uni Chem Technol, Prague, CZ): Electrochemical Behaviour of Ferrocene-Based Redox Polymer for Catalyst Recycling.
22. **Jakub Vobořil** (Uni Pardubice, CZ): The First Study of Systemic Herbicide Dicamba Oxidation and Its Voltammetric Determination on Boron-Doped Diamond Electrode.
23. **Xin Zhou** (FAU, Erlangen-Nürnberg, DE): Pt Single Atoms Loaded on Thin-Layer TiO₂ Electrodes: Electrochemical and Photocatalytic Features.

Selected presentations can be found on the web page of this seminar³. From the above overview, it can be seen that in the case of classical electroanalytical applications (see, e.g., presentations 2, 10, 15, 16, 22), attention is paid, in accordance with current trends, in particular to new electrode materials and arrangements and their possible combination with a suitable pre-separation of the analyte of interest. A number of other presentations (e.g., 1, 12, 14, 23) use elegant combinations of modern electroanalytical and spectrometric or separation methods. Finally, presentations 6, 11, 17, 19, 21 make innovative use of modern electroanalytical methods in the study of mechanisms, synthetic processes, the study of processes in various types of batteries, and processes related to the anticipated hydrogen economy.

3. Modern trends in electroanalytical chemistry

The growing demand for the cheapest, fastest, and most user-friendly analytical methods that meet the requirements of both "green" (ref.⁶) and "white" (ref.⁷) analytical chemistry is of course also reflected in the field of modern electroanalytical methods, which can often meet the requirements related to large-scale monitoring of important analytes in the field⁸ (*on-site* analysis) or at the patient's bedside⁹ (POCT, point-of-care testing). In the opinion of the author of this article, research and development in the field of modern voltammetric methods is responding to this, in particular by developing and testing new electrode materials and their arrangement and preparation of chemically, biologically, or otherwise modified electrodes. Another important area responding to the ever-increasing demands for the development of analytical methods is the field of electrochemical measurements in flow systems. The growing demands for "green" analytical methods are undoubtedly catalysing developments in the miniaturization of electroanalytical methods, and the increasing requirements for selectivity are then opening the way for further spectacular developments in modern electrophoretic methods. It is gratifying that in the year in which we commemorate the 100th anniversary of the independence of our Department of Analytical Chemistry at the Faculty of Science, Charles University in Prague, it can be stated that all the above-

mentioned modern trends are successfully promoted in research and teaching in our Department. And it is obvious that they are increasingly reflected in the focus of our CBSEC. It is also important to note that university departments in particular need to focus on bridging the significant gap between basic research and its practical applications. While in basic research, novel and relatively complex approaches and procedures are preferred, corresponding to the analytical community's idea of so-called excellent research, analytical practice, on the contrary, prefers the simplest and most user-friendly procedures.

3.1. Voltammetric methods

The successful development of new electrode materials and arrangements in our Department and in our UNESCO Laboratory of Environmental Electrochemistry is documented, for example, by recent publications on boron-doped diamond electrodes^{10–12}, which have been systematically studied at our Department for a quarter of a century^{13–15}. An interesting example is the study of selected nucleotides and dsDNA on ultrananocrystalline boron-doped diamond at extremely negative potentials¹⁶. It is worth considering whether it would not be a good idea to pay attention to the oxygen or hydrogen surface termination of working electrodes, commonly studied for boron-doped diamond electrodes, as well as for other carbon matrices. In general, it is interesting to note that, according to the Academia server¹⁷, the term "Solid State Electrochemistry" appeared in a total of 112,492 publications, which documents the extreme importance of this topic in current research. In addition to working electrodes, considerable attention is also paid to reference electrodes, without which the proper functioning of modern voltammetric techniques cannot be imagined. A qualitative comparison of reference electrodes based on different metallic materials can be found in the work¹⁸. For monitoring electrochemically reducible substances, various types of amalgam electrodes, also systematically studied at our Department, offer interesting possibilities¹⁹. Screen-printed electrodes are probably the most important substrates for biochemically modified electrodes for various types of biosensors today²⁰, and a good overview of applicable materials for 3D screen printing in electrochemistry can be found in the work²¹. The well-known saying "enzymes are the best chemists" is confirmed by the excellent sensitivity and selectivity of various types of such modified biosensors, whose problematic aspect, however, usually remains limited stability and sometimes quite complicated preparation. Therefore, in practice, electrodes modified with more stable chemical modifiers are often preferred, such as the studied glassy carbon electrodes modified with polyethylenimine and silver nanoparticles on titanium dioxide, which have proven successful in the determination of creatinine²², and the laser-reduced graphene oxide electrodes we have used for the

determination of the insecticide Carbosulfan²³, carbon ink modified carbon electrodes with a nickel-containing chromatographic sorbent used for the determination of the pesticide Carbofuran²⁴. And last but not least, a non-enzymatic sensor for cholesterol determination based on the chemical modification with a substance whose structure corresponds to the active centre of the enzyme concerned^{25,26}, but which is considerably more stable than this enzyme, is of interest. Further dissemination of the various types of voltammetric methods in practice will undoubtedly require both an emphasis on their importance in undergraduate analytical chemistry teaching²⁷ and their more prominent promotion at various wide-ranging analytical conferences. In this context, the Electro-analytical Chemistry Study Group²⁸ of the Division of Analytical Chemistry of EuChemS can play an important role.

3.2. Electrochemical measurements in flow systems

The main advantages of this approach are the significant reduction of the determination time, the reduction of the consumption of various reagents and solvents, the possibility of easy automation and miniaturization, good compatibility with both "green" and "white" analytical chemistry (the teaching of which is well covered in the paper²⁹), and, last but not least, the minimization of problems with the passivation of working electrodes³⁰. The issue of electroanalytical measurements in flow systems and their advantages and limitations is discussed in detail in the already cited output of an IUPAC project focused on this area⁵. Here, therefore, we will only briefly refer to interesting selected recent works from our Department. These include the use of an unconventional carbon film electrode based on microcrystalline natural graphite for the determination of 5-aminoquinoline by flow injection analysis³¹, the use of batch injection analysis (BIA) for DNA monitoring³², and a review paper on the potential of BIA³³. Flow injection analysis (FIA) using a spatially separated reactor with immobilized enzyme and a tubular or screen-printed solid amalgam detector monitoring the nascent product also offers interesting possibilities^{34,35}. An unconventional arrangement is the aforementioned flow-through working electrode based on porous diamond¹². Further interesting details can also be found in an article published in *Chemicke Listy*³⁶.

3.3. Miniaturization in electroanalytical chemistry

The driving force behind this process is both the desire to be as compatible as possible with "green" analytical chemistry and to keep acquisition and operating costs as low as possible by reducing the consumption of various reagents and solvents. The transition from working with volumes in the order of 10–100 mL to volumes in the order of 1 mL to 10 μ L was quite smooth and trouble-free. However, the transition to smaller

volumes in the order of fractions of μL to nL brings a certain decrease in user-friendliness, greater demands on the experimental skill of the electroanalytical chemists, problems with spontaneous evaporation of the sample, especially when working in mixed aqueous-organic environments, and with the eventual removal of oxygen from the sample. Therefore, it is usually only when there is a minimum volume of sample available, e.g., cerebrospinal fluid from a newborn baby, that one moves to this lowest scale. Interesting examples from our laboratory include work on the potential of miniaturized screen-printed carbon electrodes modified with ethyl cellulose and biochar³⁷, a renewable silver film amalgam electrode based on a click pencil³⁸, or on a single silver amalgam crystal³⁹, and, last but not least, a study focused on new types of solid reference electrodes applicable in miniaturized flow electrochemical cells¹⁸.

3.4. Capillary electrophoresis and related methods

Although capillary electrophoresis (CE) is logically classified as a separation method, it uses electrochemical principles and processes in both the separation and detection phases. The fascinating possibilities of these techniques in the medical and biological sciences have been documented, e.g., in paper devoted to the study of the metabolism of ketamine enantiomers in rat blood plasma using CE with a cyclodextrin-based chiral selector and an electrospray ionization/MS (ESI/MS) detector⁴⁰, review papers focusing on CE advances in plant analysis⁴¹ or in the field of contactless conductivity detectors⁴², or inspiring papers describing a coaxial flow probe for electro-membrane extraction of methadone coupled on-line with CE (ref.⁴³), microdialysis of body fluids for amino acid monitoring using CE with contactless conductivity detection⁴⁴, or direct coupling of sample preparation to CE or electrophoresis on a microchip⁴⁵. Other inspiring work in this field generated at our Department includes the use of liposomal electrokinetic chromatography for monitoring drug-membrane interactions⁴⁶ and capillary surface modification for CE separation of liposomes⁴⁷.

4. Conclusion

Finally, I would like to mention some other modern trends in the field of electroanalytical methods that have not yet appeared at the cross-border seminar, but which we would like to see there in the coming years. Examples include electrochemical sensors based on a combination of VMSF (vertically-ordered mesoporous silica films) and ErGO (electrochemically reduced graphene oxide) with strong anti-biofouling properties (resistance to passivation by various microorganisms or algae)⁴⁸, electrodes based on the so-called "bucky paper" prepared from polystyrene and MWCNTs (multi-walled carbon nanotubes) in the form of a disk⁴⁹, electrochemical paper-based analytical devices

(ePADs)^{50,51}, electrodes based on tetrahedral amorphous carbon with embedded nitrogen (ta-C:N)⁵², which are optically transparent and have similar properties to BDDs, and many others. Activity in these areas will be a most worthy commemoration of a significant anniversary of our Department.

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