



## Electrochemical traditions in Eastern Europe

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The edition of this special issue started in early 2022—that is, at a time when the decay of the COVID-SARS-19 pandemic could already be foreseen, but before a new war broke out in the region, impacting also scientific research and international collaborations. We are grateful to all our colleagues who contributed to this issue prepared in such a difficult period. The present issue inherits the spirit of the book “Electrochemistry in the Divided World” [1], but with an essential difference: we try to highlight the development of electrochemistry in both “large” and “small” countries and to accent individual scientific features of the electrochemical research of particular countries and/or regions. The issue starts a new collection, which will hopefully be extended by colleagues from various countries mentioned below.

Eastern Europe is a conditional term which is closely associated with the former “socialist” countries <In contrast to Ref. [1], there is nothing in this issue from the former German Democratic Republic, which is now a part of a Central European area. All the countries of the former Yugoslavia are included despite Slovenia is a part of Central Europe in accord with some definitions>. Fortunately, nowadays, many of them solidly belong to the European Union and undergo the development of their research in the absence of limitations described in Ref. [1]. Great electrochemical schools which existed in Eastern Europe even under “soviet” pressure are undergoing natural evolution. However, currently,

active generations of electrochemists are still under the influence of the professional traditions of these schools, and their international integration still allows them to keep certain individuality. This is in favor of further dissemination of basic knowledge. We also noticed a lot of joint publications of electrochemists from different Eastern European countries. Sometimes, this stems from long-term cooperations started even before the collapse of the soviet political block but may also stem from more recently established networks like the Association of South-East European Electrochemists (ASEEE) [2].

Following the approximate geographic definition, we invited the authors from the countries *mentioned below in alphabetic order*. The issue collects the reviews covering electrochemistry in either various countries and—in the case of larger or less homogeneous communities—in some separate regions, or related to separate topical branches. Original articles are presented as well. Although we strived for completeness and committed everything to recruit contributions from each single part of the Eastern Europe, it was impossible to collect the reviews from all the countries for various reasons. In such instances, we present our obviously non-exhaustive brief comments in this introductory article.

Electrochemistry in **Albania** is mostly presented by corrosion/protection studied by individual researchers, typically in cooperation with other countries. There are also some publications in the field of electroanalysis. Albanian publications in specialized electrochemical journals are very rare, and there are no ISE members from Albania. This is also the case for **Armenia**, where electrochemical techniques and approaches are mostly applied in frames of interdisciplinary research (e.g., medical diagnostics, materials for various devices, organic electrosynthesis). The most noticeable electrochemical publications from **Azerbaijan** address the electrodeposition of binary alloys and compounds. This country tends to cooperate mostly with Asian partners in scientific research <Formally, both Armenia and Azerbaijan are outside Europe, but we mention these countries as the Caucasus part of the former Soviet Union, which is located close to or at the ambitiously determined boundary between Asia and Europe>.

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Electrochemistry in **Belarus** (no review in this issue) is keeping up with several traditional directions, which are also disseminated by the strong Belarusian electrochemical diaspora. The basic institution is Belarusian State University (BSU), with a long tradition of semiconductor electrochemistry and photoelectrochemistry [3–5], impedance spectroscopy [6, 7], ion-selective electrodes [8], and also corrosion protection and electrocatalysis. Several BSU Departments hosted electrochemical research, and the Department of Electrochemistry at BSU was founded in 2010. In the past, solid-state chemistry research at BSU strongly affected electrochemistry. This resulted in the appearance of a photoelectrochemical and nanoelectrochemical branch founded by Vadim V. Sviridov (1931–2002) and a solid electrolyte branch [9–12] founded by Alim A. Vechar (1933–2011); later, this branch partly relocated to Western and Eastern Europe, Russia, and the USA. Other institutions hosting electrochemical science in Belarus also include (but are not limited to) the former Radiotechnical Institute transformed in the 1990s into Belarusian State University of Informatics and Radioelectronics (BSUIR), Belarusian State Technological University (former Technological Institute), and Institute of General and Inorganic Chemistry of the National Academy of Sciences. Vitali P. Parkhutiuk (1951–2006) who had moved from BSUIR to Spain is widely known in the electrochemistry of porous semiconductors [13].

Electrochemistry in **Bosnia and Herzegovina** is considered in the review of M. Mitrovic. **Bulgaria** is presented by the review of V. Tsakova. The readers are also invited to read a chapter of the late A. Milchev (1933–2022) in [1] (p.401–430). The review of M. Kraljic Rokovic describes electrochemistry in **Croatia**. For the **Czech Republic**, a chapter by J. Jindra and M. Heyrovsky is available in [1] (p.13–48) and supplemented by a review of J. Ludvik in this issue. A team from **Estonia** (E. Lust et al.) contributed to the issue with extensive review considering the way from double-layer research to electrochemical devices. Two separate branches of electrochemistry in **Georgia** are considered in reviews of D. Khoshtaria et al. (charge transfer research) and N. Nioradze (manganese electrochemistry). The recent situation in **Hungary** is summarized by T. Pajkossy, which is the follow-up of the works of G. Inzelt (chapter available in [1] (p. 359–399) as well as an earlier historical survey [14]). A wide range of electrochemical activities in **Latvia** is considered by G. Bajars et al. Latvian organic electrochemistry branch is briefly reviewed in Ref. [1] (p.274–276).

We received no review from **Lithuania**. Earlier electrochemistry having a long and storied tradition in this country was described by R. Ramanauskas in [1] (p.179–210). The Centre for Physical Sciences and Technology (FTMC) in Vilnius houses a large electrochemical research facility with numerous specialized techniques. In addition, electrochemistry is located at the Faculty of Chemistry and the

Centre for Life Sciences at Vilnius University, in Vilnius Gediminas Technical University and Kaunas University of Technology. In parallel with traditional Lithuanian areas of electrochemical material science like electrodeposition [15] and corrosion [16, 17], active research of electrochemical sensors [18] is in progress, which is closely linked to the electrochemistry of conducting polymers [19]. Metal-ion batteries present a new intensively developing direction [20]. Interfacial electrochemistry is represented by bilayer membrane research [21].

A detailed introduction to the past and present of the electrochemical research in **Moldova** is presented by A. Dikusar, A. Cuharuc, and N. Tsyntsaru, supplementing the subsection written by J. D. Sister in [1] (p.140–155).

With respect to electrochemistry in **North Macedonia**, electroanalysis seems to be the main branch [22, 23]. Electrochemists are concentrated at the Faculty of Technology and Metallurgy of the University Ss Cyril and Methodius in Skopje, and also in Goce Delcev University of Stip. We should also mention the worrisome thoughts about the future of electrochemistry in a Macedonian publication [24].

**Poland** is known for its wide and diverse electrochemical community, which was partly presented in Ref. [1] by Z. Galus (p.315–331) and J. Lipkowski (p.333–358). In this issue, their texts accenting the *Warsaw* branch are supplemented by a review dedicated to the activities of the *Krakowian* region (by P. Zabinsky and K. Skibińska).

**Romania** keeps a long and diverse electrochemical tradition. In *Bucharest*, Polytechnica University hosts the Department of Inorganic Chemistry, Physical Chemistry and Electrochemistry with a long past of electrode kinetic research, including applied topics. This and some other Politechnica units interact with Electrochemistry and Corrosion Department in “Ilie Murgulescu” Institute of Physical Chemistry, Romanian Academy of Sciences. There are also groups at the Faculty of Physics and Faculty of Chemistry, University of Bucharest, in the National Institute of Materials Physics (Magurele, near Bucharest), and in the National Research-Development Institute for Electrochemistry and Condensed Matter (INCEMC) located both in Bucharest (Laboratory of Electrochemistry and PATLAB) and Timisoara. In *Cluj-Napoca*, Babeş-Bolyai University hosts an electrochemical school founded by Professor Liviu Oniciu (1927–1999). Now this institution is known for Research Center in Electrochemistry and Non-conventional Materials. Simultaneously, corrosion and electrodeposition research highlights the use of various electrochemical experimental techniques related to these topics. There are also electrochemical groups at various departments of Babeş-Bolyai University, in Iuliu Hațieganu University of Medicine and Pharmacy, and in the National Institute for Research & Development of Isotopic & Molecular Technologies. Outside the two largest cities, electrochemistry in Dunarea de Jos University

*Galati*, Transilvania University *Brasov*, National Institute of Research and Development for Technical Physics in *Iasi*, and the Polytechnic University of *Timisoara* should be mentioned. For several decades, Romania was known for its electrodeposition and corrosion research, which are still active and closely interrelated [25, 26]. Prof. Teodor Visan (1943–2023), one of the important Romanian electrodeposition persons, passed away recently. Ongoing studies of deposition from ionic liquids and deep eutectic solvents probably inherit the tradition of melt electrochemistry, which was rather solid in Romania in the twentieth century. Now these studies are well developed not only from the electrochemical side, but also from the material science side as well. More recent battery research seems to continue this tradition [27]. The trend one can easily observe from the literature is a sharp growth of sensor-related electrochemical topics in Romania. Refs [28–34] present a list of reviews in this area.

For various aspects of electrochemistry in **Russia**, one can find a lot of information in Ref. [1]: O. Petrii and S. Fletcher wrote about the Frumkin School (p.49–96), F. Scholz et al. collected a lot of data about electroanalysis as developed in various regions (p.97–178), A. Demin and P. Shuk described solid-state electrochemistry developed in the Uralian area (p.229–255), and V. Mairanovsky covered organic electrochemistry topics (p.257–314). Later, the links of the Frumkin School with power sources research were reviewed [35]. There are still three specialized departments of electrochemistry in *Moscow*, *St.Petersburg*, and *Rostov-on-Don*. The currently existing Frumkin Institute is the former Institute of Physical Chemistry merged in 2005 with the much smaller Institute of Electrochemistry founded originally by Frumkin. Another specialized institution in the Russian Academy of Sciences is the Institute of High-Temperature Electrochemistry in *Ekaterinburg*. During recent years the community lost widely recognized members: Boris Damaskin (1932–2019), Oleg Petrii (1937–2021), Lev Krishtalik (1927–2022), Yury Chizmadzhev (1931–2022), and Valery Malev (1939–2022).

The contribution of electrochemists from **Serbia** to the world of electrochemistry can be read from the pen of N. Elezovic.

There is no review from **Slovakia**, but the history of electrochemistry in this country is partly presented in the Czech (Czechoslovak) texts mentioned above. The active group dealing with the electrodeposition of functional coatings and nanomaterials [36–39], electrochemical sensors [40, 41], and batteries [42] is known at Pavol Jozef Šafárik University in *Kosice*. This University also houses the material science group, which is partly dealing with electrocatalysts [43, 44]. Sensor-oriented electrochemical research is visible in the Slovak University of Technology in *Bratislava* and the Institute of Chemistry, Slovak Academy of Sciences [45–47].

**Slovenia** hosts high-level material science-oriented electrochemical research in the field of energy conversion and storage, mostly concentrated in the National Institute of Chemistry [48, 49], where the late Janko Jamnik (1964–2014) [50] had created the tradition of Li battery research earlier. This Institute is also famous for electrochromic topics [51]. Specialized educational programs related to electrochemical material science are supported by Ljubljana University. There is a strong corrosion-oriented department at the Jozef Stefan Institute in *Ljubljana* as well [52]. Electrochemical analyses are addressed in *Ljubljana* [53] and *Maribor* [54].

Texts about electrochemistry in **Ukraine** are available in [1]: electrochemistry in *Kiev* by A. Andriiko (p.211–227), a brief summary of electroanalytical research in *Donetsk* (p.130–132), and very brief notes on organic electrochemistry (p.277). This information is far from exhaustive for such a large country with deep electrochemical research traditions and a wide variety of electrochemical topics. Ukrainian State University of Chemical Engineering in *Dnipro* (former Dnepropetrovsk) keeps a very active team dealing with the electrodeposition of metals, oxides, and compositions [55, 56]. *Kharkiv* [57] hosts electrochemistry at two famous universities. National University named after Karazin is well known for the electrochemistry of solutions. These studies are continued in frames of traditions of Nikolay Izmailov School [58] and also address solvent-dependent properties of heterogeneous systems [59]. In the Technical University (Kharkiv Polytechnical Institute, KPI), applied electrochemistry is dominating, as well as basic research related to galvanics [60]. Boris Bairachniy (1935–2020), a long-term head of this KPI department, passed away recently. Kharkiv electrochemists are also affiliated with other smaller Universities in the city. Electrochemists from Ivan Franko National University and Polytechnical National University are active in *Lviv*, having active cooperation with Poland, Slovakia, and Germany. There are various branches of electrochemical material science [61, 62], and sensor-oriented research [63]. Karpenko Physico-Mechanical Institute of the National Academy of Sciences in *Lviv* is known for its studies of corrosion [64]. Electroanalytical publications [65] are typical for Mechnikov National University in *Odessa*, which are closely related to solution equilibria. There are many other electrochemical places in Ukraine, including *Chernivtsi*, *Donetsk*, *Poltava*, *Simferopol*, *Uzhgorod*, and *Zaporozhe*. In spite of the dramatic war surrounding it, science is still in progress in Ukraine. Our hope is to publish a systematic review about electrochemistry in Ukraine when the country is liberated and starts to recover.

A number of special issues of this journal were dedicated earlier to various electrochemists from Eastern Europe: Zbigniew Galus from Poland (2004, No 10),

György Horányi from Hungary (2005, No 5), Oleg A. Petrii from Russia (2008, No 4), Nina F. Zakharchuk from Russia (2012, No 7), Alexander Milchev from Bulgaria (2013, No 2), Anna Brainina from Russia (2013, No 6), Vladimir S. Bagotsky from Russia (2014, No 5), Mikhail A. Vorotyntsev from Russia (2006, No 3, and 2015, No 9), George Inzelt from Hungary (2011, No 11–12, 2016, No 11, and 2021, No 12), Šebojka Komorsky-Lovrić and Milivoj Lovrić from Croatia (2016, No 12). These issues can be considered the particular examples demonstrating the deep integration of Eastern European electrochemists into international research in the area.

The countries of Eastern Europe hosted many conferences, including CITCE (Comité International de Thermodynamique et de Ciéntique Electrochimiques, ISE predecessor) and ISE meetings in Moscow (1962), Budapest (1964, 1978), Prague (1969, 1990, 2012, 2022), Dubrovnik (1970), Druzhba (1977), Cavtat (1981), Vilnius (1986, 2018), Veszprém–Balatonfüred (1996), Warsaw (2000), Szczyrk (2009), Szeged (2017), Belgrade (2020), and Mikulov (2021). Several series of more specialized conferences mostly or completely located in Eastern Europe are the Baltic Conference on Electrochemistry (special issue of this journal was published in 2008, No 4), Workshop “Electrochemistry of electroactive materials” (WEEM, special issues 2007, No 8, and 2010, No 11), Frumkin Symposium, Heyrovsky Discussions, Regional Symposium on Electrochemistry of South-East Europe, Mátrafüred International Conference on Electrochemical Sensors, International Workshop on Electrodeposited Nanostructures (EDNANO). Some Kurt Schwabe Symposia and E-MRS Meetings were arranged in Eastern Europe as well (see the special issue of this journal published in 2014, No 11, and 2017, No 12, respectively). The former “iron curtain,” though it was raised for preventing the process, triggered the outflow of active scientists from Eastern Europe. The scale of relocation has increased after the fall of this curtain in the 1990s, resulting in the appearance of many strong scientific diasporas. Interactions of diaspora with electrochemists in the native countries affect essentially the development of electrochemistry in Eastern Europe, as the reader will notice from a number of reviews in this issue. Let us hope that the impact of the positive feedback from the Eastern European-born scientists will remain the same in the future, and the mobility will not be forced by war and restrictions of freedom but induced by the natural professional reasons, possibly also in a bidirectional manner.

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