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FEATURE ARTICLE

Paving the way for electrochemistry in Croatia: activities and the most important scientists

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Abstract

The article describes the development of electrochemistry at research institutions in Croatia. The foundation of electrochemistry in Croatia has been laid throughout the work of professors of Technical Faculty at the University of Zagreb M. Karšulin, B. Lovreček, and I. Filipović starting from 1930's. Their work was related to corrosion processes, photoelectrochemistry, organic electrochemistry, and complex stability. M. Branica and V. Pravdić initiated electroanalytical activities at Ruđer Bošković Institute by using polarography, voltammetry, and chronopotentiometry. All these activities helped spreading of electrochemistry at higher education and research institutions in Zagreb, Split, and Osijek. Today, the new generation of scientists is continuing research in this field. The electrochemical community in Croatia is small but very active, which is visible by *Regional Symposium on Electrochemistry of South-East Europe* initiation and organization, by activities in the *Association of South-East European Electrochemists*, by activities in the *International Society of Electrochemistry*, as well as by encouraging doctoral students to organize *ISE Satellite Student Regional Symposium on Electrochemistry*.

Keywords Croatia · Electrochemistry · History · Higher education · Research · Scientific institutes

The development of electrochemistry in Croatia is closely related to the development of higher education and scientific institutes. The beginnings of research in the field of electrochemistry correspond with the establishment of the Chemical-Technical Department (1919) at the Technical High School in Zagreb (from 1926: Chemical-Engineering Department at the Technical Faculty). The first records of research in the field of electrochemistry date from *Rikard Podhorsky* (1902–1994), who defended his doctoral thesis entitled "Investigation of Corrosion of Metals" at the Technical Faculty in 1931. However, his further research was focused on other topics in the field of chemical engineering. *Miroslav Karšulin* (1904–1984) was one of the most important figures that founded the basis of electrochemistry in Croatia (Fig. 1). In 1932, he defended his doctoral thesis "About the Becquerel Effect" at the Technical Faculty (later Faculty of Technology) of the University of Zagreb, where he continued his career as a professor. The main interests of his long and fruitful work were photochemistry, electrochemistry, corrosion, and protection, as well as the physical chemistry of silicates. He worked on periodic potential oscillations of iron in nitric and chromosulfuric acids, passivity and corrosion of various metals in acids, sea and drinking waters, as well as on cathodic protection and corrosion inhibitors. As early as 1948, he introduced the optional course for undergraduate students "Technical electrochemistry," while in 1960, he was one of the initiators of the new postgraduate study "Corrosion and protection of metals." M. Karušiln was a full member of the Yugoslav (now Croatian) Academy of Sciences and Arts—JAZU and one of the initiators of the establishment of the scientific research unit of JAZU (now HAZU) "The Institute of Corrosion Research and Desalination" in Dubrovnik in 1965 [1].

Branko Lovreček (1920–1996) was another important figure in education and research in the field of electrochemistry, working at the Faculty of Technology at the University of Zagreb (Fig. 1). He defended his PhD thesis in 1952 under the mentorship of M. Karšulin with the topic of the electrochemical oxidation of nicotine. B. Lovreček was a visiting researcher at Imperial College in London (1952–1953) and University of Pennsylvania, Philadelphia (1957–1959), where he worked with the famous electrochemist J. O'M. Bockris. In 1960, he established a new department at the

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Fig. 1 Branko Lovreček (first from the right) and Miroslav Karšulin (second from the left) during Yugoslav conference on electrochemistry in 1979, Dubrovnik

Faculty of Technology—the Department of Electrochemistry and Electrochemical Technology. This significantly increased the number of courses in electrochemistry and electrochemical engineering taught at the faculty. Even more, this led to a significant upgrading of electrochemical science in Croatia. Professor B. Lovreček and his group have successfully conducted research in many areas of electrochemistry: electrochemical engineering, corrosion, mechanisms of electrochemical reactions, adsorption, organic electrochemistry, bioelectrochemistry, electrochemistry of semiconductors, and photoelectrochemistry. They also translated the first handbooks on electrochemistry into Croatian—Electrochemistry: Principles & Application (Edmund C. Potter) and Electrochemical Engineering (Charles L. Mantell) [2, 3].

One of the professors at the Faculty of Technology was *Ivan Filipović* (1911–1998), who got his PhD in 1951 ("Polarographic study of bismuth amalgam") (Fig. 2). He worked at the Faculty of Pharmacy and afterwards began his career at the Faculty of Technology in 1954. His investigation was focused on equilibria in solutions of complex compounds, electrode processes, and analytical chemistry, and he was the first to introduce polarography to Croatian science and practice. His first paper in the field of polarography was published in 1943 and dealt with the determination of gold in gold-bearing ores [4]. This was the first polarographic work published in Croatia (the former Yugoslavia).

During their fruitful research work, M. Karšulin, B. Lovreček, and I. Filipović raised many generations of electrochemists who continued their work. Ksenija Moslavac, Ljerka Duić, Mirjana Metikoš-Huković, and Đani Matić were doctoral students of B. Lovreček who were teaching and doing scientific work at the Department of Electrochemistry.

Ksenija Moslavac (1930–2018) (dissertation thesis: "Electrochemical studies of semiconductor-electrolyte contact,"

Fig. 2 Ivan Filipović (second from the left) with students during 1960s at Faculty of technology, University of Zagreb

1964) was a professor at the Department of Electrochemistry. She was teaching courses on electrochemistry and corrosion. Her research interests were in the field of semiconductors passivation and dissolution of metals and bioelectrochemistry (electrochemical properties of collagen fibres) [3].

Ljerka Duić (1935–2022) (dissertation thesis: "Studies on the mechanism of electrochemical reduction of tetravalent germanium," 1964) became a professor in the same department, focusing her work on organic electrochemistry, electrochemical energy conversion, and the application of conducting polymers in catalysis and corrosion protection. She started research on conducting polymers in the mid-eighties and made a significant contribution to this field. She was a post-doctoral student at the University of Pennsylvania (1965–1967), a visiting scientist at New York University (1969–1971) and the University of Ottawa (1979/1980). She was the author of three student handbooks and the first women's vice dean at University of Zagreb [3].

Mirjana Metikoš-Huković (1937-) (dissertation thesis: "Electrochemical studies of the valve-metal electrolyte system," 1974) continued her professional career in the same department. During her doctoral studies (1967–1970), she worked in the research group of Prof. Ewald Heitz, Dechema Institute, Frankfurt am Main, Germany. She was a visiting scientist at the Fritz Haber Institute of the Max Planck Society in Berlin (1977/1978) in the research group founded by Prof. Heinz Gerischer and Dr. Karl Doblhofer, working on the electrochemistry and photochemistry of semiconductor materials. She was also a visiting professor at the Jülich Research Centre, Jülich, Germany (1993/1994), where she worked with Prof. Ulrich Stimming on the application of bimetallic catalyst materials for electrocatalysis and energy conversion. Her broad scientific interests also include studies on the passivity of metals, the biocompatibility of metallic materials and the role of alloying elements, electrochemistry of interfaces and thin films, electrocatalysis of hydrogen evolution reaction, self-assembled monolayers, corrosion protection by corrosion inhibitors and organic coatings. During her long and fruitful career, she has published over 130 scientific papers in Current Contents indexed journals and co-authored one book and five book-chapters. She is the most cited researcher of the Faculty of Chemical Engineering and Technology (successor of Faculty of Technology). She has also mentored many PhD students, nowadays distinguished electrochemists who continued their careers outside Croatia (Sasha Omanovic—McGill University (Canada), Nushe Lajci—University of Prishtina, Emir Turkušić—University of Sarajevo (Bosnia and Herzegovina), and Zora Pilić—University of Mostar (Bosnia and Herzegovina)). M. Metikoš-Huković was the first regional representative of Croatia in the International Society of Electrochemistry from 1994 to 1996. She became professor emerita in 2008 [5].

Đani Matić (1943–2006), also a student of Professor Lovreček, was one of the pioneers in the field of electrochemical engineering. B. Lovreček and Đ. Matić introduced several courses on electrochemical processes and electrochemical engineering into the curricula of the Faculty of Technology. Đ. Matić started research in this field during his master's thesis, followed by his PhD thesis, "Study on mass transfer in electrochemical reactions" (1977). He was a postdoctoral student at ETH, Zurich, Switzerland, where he worked with Professor Norbert V. Ibl, one of the founders of electrochemical engineering. His scientific interests included the merging of electrochemical and hydrodynamic properties of various systems and the modelling of electrochemical reactors. He also wrote a student handbook, "Electrochemical engineering." In 1993, he left the Faculty and joined ETH Zurich, where he continued his scientific work until his retirement [3, 6].

Ema Stupnišek-Lisac (1943-) is a former PhD student and collaborator of M. Karšulin at the Department of Physical Chemistry. Part of her doctoral research on corrosion and passivation of iron in nitric acid was carried out in the laboratory of Israel Epelboin at the University of Paris (later University Pierre and Marie Curie) (1973–1974). During her career, she continued to collaborate with researchers from this university, especially with Hisasi Takenouti. Later, she moved to the Department of Electrochemistry of the same Faculty, where she devoted her scientific career to corrosion studies, especially the phenomenon of passivity and corrosion inhibition. She has published numerous papers on non-toxic corrosion inhibitors for various metallic substrates.. She is author of one student handbook on corrosion.

Many other students and collaborators of M. Karšulin continued research in the field of corrosion at other faculties of the University of Zagreb. *Olga Šarc-Lahodny* (1928–2016) worked at the Faculty of Mining, Geology and Petroleum Engineering, and was also the head of the Institute for Corrosion Research and Desalination in Dubrovnik. One of the areas of her scientific interest was corrosion, especially corrosion inhibition and crevice corrosion. *Nada Ciković* (1938–2005) worked at the Faculty of Food Technology and Biotechnology and, together with her colleague *Katarina Berković* focused on the corrosion of metallic food packaging and aluminium corrosion. *Miroslav Gojo* (1950-) worked at the Faculty of Graphic Arts, focusing his research interests mainly on electroplating.

It is also worth mentioning that the Department of General and Inorganic Chemistry at the Faculty of Technology boasted one of the first laboratories in the world with computerised electrochemical (polarographic) measurements. It was established in the 1970s in the laboratory of Professor I. Filipović and his collaborators *Božidar Grabarić*, *Mihael Tkalčec*, and *Ivan Piljac*, who carried out electroanalytical studies to determine the stability constants of complexes by the polarographic

methods (Fig. 3). B. Grabarić later continued his work at the Faculty of Food Technology and Biotechnology, focusing on the analysis of voltammetric data and later on the development of electrochemical biosensors. B. Grabarić was the supervisor of two scientists who continued their activity in this field, namely *Stjepan Milardović* (1958–2021), who worked at the Faculty of Chemical Engineering and Technology, and *Damir Iveković*, who is still working at the Faculty of Food Technology and Biotechnology [7].

Nowadays, a new generation of scientists at the Department of Electrochemistry, Faculty of Chemical Engineering and Technology, University of Zagreb is continuing research in the field of electrochemistry. *Sanja Martinez*, *Helena Otmačić Ćurković*, and *Jozefina Katić* work in the field of corrosion, especially corrosion inhibitors, organic and ceramic coatings, and corrosion measurements; *Marijana Kraljić Roković* (Regional representative for Croatia in International Society of Electrochemistry from 2015 to 2020) focuses on conducting polymers, energy power sources, nanomaterials, and photoelectrochemical processes and *Zoran Mandić* on conducting polymers, organic electrochemistry, bioelectrochemistry, and energy power sources.

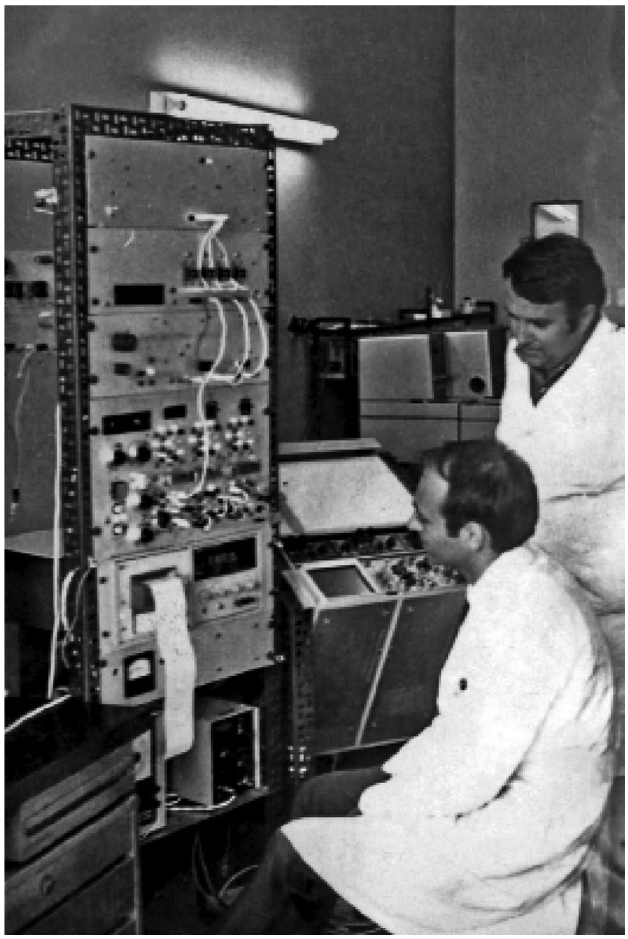

Fig. 3 Božidar Grabarić (right) and Mihael Tkalčec (left) with the homemade computerised polarographic instrument at Faculty of Technology, University of Zagreb in the mid-seventies [7]

At the Faculty of Mining, Geology and Petroleum Engineering, research in the field of corrosion is continued by *Frankica Kapor* with her younger colleague *Gordana Bilić*. Another electrochemist working at the same faculty was *Palma Orlović-Leko* (now retired), whose work first was devoted to corrosion and metal protection, and afterwards, she was involved in characterisation of organic matter by electrochemical methods as external associate of the projects of Institute Ruđer Bošković.

Ruđer Bošković Institute (established in 1950) is the second crucial institution for the development of electrochemistry in Croatia. Responsible for that was *Mirko Mirnik* (1917–1999), Professor Emeritus of Faculty of Science, University of Zagreb, who established the first electrochemical laboratory within the former Department of Physical Chemistry at the newly established institute. M. Mirnik was a versatile and productive scientist, with scientific interests not only in electrochemistry, but analytical chemistry, radiochemistry, and colloid chemistry too. In the field of electrochemistry, M. Mirnik was the first who applied potentiometry using ion-selective electrodes, while the series of his papers published in 1960s (in collaboration with Velimir Pravdić) on the electrokinetic stability of disperse systems, made the basis for his later theory on the point charge model of electrical double layer [8].

Prof. Mirnik's PhD student Velimir Pravdić and his contemporary Marko Branica have great merits for further development of scientific and research activities in the field of electrochemistry in the former Department of Physical Chemistry of the Ruđer Bošković Institute. Their common activities began with the electrochemical production of uranium dioxide in the early 1960s and over the years, both became oriented toward studies important for environmental protection. They spent their entire careers at the Ruđer Bošković Institute, Marko Branica from 1954 until he died in 2004 and Velimir Pravdić from 1956 until he died in 2011.

Marko Branica (1931–2004) was a leading Croatian marine scientist and physical chemist. He received his PhD from the Faculty of Natural Sciences at the University of Zagreb in 1963, with the thesis on "Extraction of inorganic ions with organic solvents" under the supervision of colloid chemist Professor Božo Težak. His contribution to electrochemical research can be seen in polarography and voltammetry of metal ions and complexes and surface active substances and analysis of trace elements. Together with *Zvonimir Pučar* (1922–1989) and Velimir Pravdić, he was involved in the development of a process for the production of uranium dioxide by the electrochemical reduction in alkaline carbonate solutions. During his career, he was the head of the Laboratory for physicochemical separations (1967–1984), the head

of the Laboratory for Physical Chemistry of Traces within the Center for Marine and Environmental Research (ZIMO) from 1984 until his retirement, and head of ZIMO since 1969. From these laboratories, other laboratories, groups and project units were developed, as well as a number of prominent Croatian scientists, professors, and experts. He paid special attention to water science and environmental protection. For his work in this field, he was awarded one of the most prestigious environmental prizes in the world, the "Amsterdam Prize for the Environment" of the Netherlands Royal Academy of Arts and Sciences (1992). His work on environmental protection was especially related to the Adriatic Sea and the Krško nuclear power plant. M. Branica got the "Ruđer Bošković" state award for science in 1982 and the national Lifetime Achievement Award in Chemistry in 1996. In 1992, he was elected a member of the Academia Europaea, London, and Academia Scientiarium et Artium Europaea, Salzburg from 1992. M. Branica organized fruitful and successful collaboration between the Ruđer Bošković Institute and the Institute of Chemistry of the Nuclear Research Center in Jülich, Germany (1970–1996). He cooperated with Hans Wolfgang Nürnberg, a well-known electrochemist and director of the Jülich Institute of Chemistry. As an established scientist and expert, M. Branica was the coordinator and principal investigator of numerous bilateral international projects and scientific research in the country. He was a full professor at the Faculty of Science, University of Zagreb. From 1971 he organized a postgraduate course in Oceanography at the Faculty of Science, University of Zagreb, which was subsequently reorganized into a doctoral curriculum at the same faculty [9, 10].

The academician *Velimir Pravdić* (1931–2011) [11] worked for a short time in the industry ("Electroda") and then spent his entire career at the Ruđer Bošković Institute (1956–2011), where in 1968 he established the Laboratory of Electrochemistry and Surface Chemistry, which was integrated into ZIMO. This period was encouraging for young scientists to visit international laboratories, which led to new ideas for scientific research as well as the introduction of new techniques into their scientific work. During this time, V. Pravdić held a postdoctoral position at Lehigh University (Bethlehem, Pennsylvania, SAD) under the supervision of physical electrochemist Albert Zettlemoyer. In the 1970s, his research activities focused on environmental protection and sustainable development. He studied mechanisms and kinetics related to the reaction of U (IV), U(VI), and Ni(II) using the chronopotentiometry method. He conducted intensive research related to electrokinetic phenomenon, and his work was also related to physical biochemistry. V. Pravdić was a member, and from 1978 to 1981 the president, of the UN Group of Experts on the Scientific Aspects of Marine Protection (GESAMP), and since 1990 actively participated in the work of the International Union for Conservation of Nature (IUCN), the largest and most important world organization dedicated to natural resource conservation. He established long-term cooperation with the National Institute for Standards and Technology, Washington D.C. and with Environmental Protection Agency. V. Pravdić was a visiting professor at Lehigh University in the USA and, for many years, a lecturer in postgraduate studies at the Faculty of Pharmacy and Biochemistry and the Faculty of Science, University of Zagreb. The electrochemists arising from the group of V. Pravdić, which were active at Ruđer Bošković Institute, are *Dunja Čukman*, *Jasenka Bišćan*, *Marijan Vuković*, and *Dalibor Hodko*.

The first generation of prominent electrochemists, who started their work in the group of M. Branica were Božena Ćosović and Vera Žutić. The further development of this group includes the following electrochemists, in an approximate chronological order, Ivica Ružić, Biserka Raspor, Zlatica Kozarac, Marina Zelić, Vesna Svetličić, Marta Plavšić, Damir Krznarić, Ivanka Pižeta, Marina Mlakar, Blaženka Gašparović, Irena iglenečki-Jušić, Nadica Ivošević DeNardis, Dario Omanović, Vlado Cuculić, Elvira Bura-Nakić, Sanja Frka Milosavljević, Slađana Strmečki Kos, Dijana Jadreško, Abra Penezić, and Marija Marguš (Fig. 4).

Professor emerita *Božena Ćosović* was active at Ruđer Bošković Institute, where she got her PhD in 1967 (Faculty of Natural Science, University of Zagreb, supervisor M. Branica, "Study of the electrochemical reduction of trivalent indium and divalent cobalt in the presence of acetylacetone"). Her research interests included the development of new analytical methods for research and control of marine, freshwater and estuarine systems, pollution monitoring and legislation. She was involved in teaching activities as a professor at the postgraduate study at the Faculty of Science, University of Zagreb, in the field of chemistry and oceanology and at the interdisciplinary doctoral study Protection of Nature and the Environment at the University of Osijek [12, 13].

Fig. 4 Marko Branica (standing right) with his group at Ruđer Bošković Institute in 1994

Vera Žutić was active at Ruđer Bošković Institute from 1963, where she obtained her PhD in 1970 (Faculty of Science, supervisor M. Branica, "Electrochemical study of uranium(VI) peroxide complex"). Her investigation was focused on interfacial processes (adsorption, adhesion, and aggregation) biogeochemical processes in the sea, processes of eutrophication of coastal and estuarine areas, supramolecular organization of organic matter and gel phase in the sea, development and application of electrochemical instrumentation, techniques and sensors for aquatic systems, marine processes on the nanoscale and modern imaging techniques (atomic force microscopy). She had a specialisation at Universitéé Libre de Bruxelles, Belgium (1971/71) and she was visiting scientist at the Swiss Federal Institute for Aquatic Sciences, ETH/EAWAG, Dübendorf, Switzerland (1980–1981), and in Scripps Institution of Oceanography, Marine Biology Research Division, UCSD, SAD, (Fulbright scholar, 1995–1996). V. Žutić got the state award "Ruđer Bošković" in 1991. She was a professor at postgraduate study at Faculty of Science, University of Zagreb, in the field of oceanology.

An oustanding contribution to the development of electrochemical methods at the Ruđer Bošković Institute was made by *Šebojka Komorsky-Lovrić* (1951–2020) and *Milivoj Lovrić* (1951-). M. Lovrić received his PhD at the Ruđer Bošković Institute under the supervision of M. Branica (1977, "Characterisation of metal traces by voltammetric methods"). Š. Komorsky Lovrić received her PhD in 1984 at the University of Zagreb, Faculty of Pharmacy and Biochemistry. During her professional career, she worked as a pharmacist (1974–1984), then as an assistant professor at the Military School of Technical Sciences in Zagreb (1988–1991), and then continued her career at the Ruđer Bošković Institute (1991–2016) [14]. She was a professor at the Faculty of Pharmacy and Biochemistry (1993–2001) and at the Faculty of Natural Sciences (University of Zagreb) (2005–2011). The scientific work of Š. Komorsky-Lovrić and M. Lovrić was mostly methodologically oriented. Their main interests were adsorptive stripping voltammetry, voltammetry of immobilised microparticles, theory of pulse voltammetric techniques, electrode kinetics, and microelectrodes. They had a fruitful and successful collaboration with the Atomic Research Institute in Jülich. They cooperated with Janet Osteryoung and Royce W. Murray (USA), Alan Bond (Australia), Fritz Scholz (Germany), and Richard G. Compton (UK). The work of M. Lovrić was mostly related to theoretical aspects and the work of Š. Komorsky-Lovrić on experimental aspects of electroanalytical chemistry. M. Lovrić published 176 and Š. Komorsky-Lovrić 146 papers. Additionally, Š Komorsky Lovrić and M. Lovrić together with F. Scholz, were awarded by Elsevier for the best cited paper for 2003 published in Electrochemistry Communications (*A new access to Gibbs energies of transfer of ions accross liquid/liquid interfaces and new method to study electrochemical processes at well-defined three-phase junctions*) [15]. They were also awarded in 2008 for the book "Square-Wave Voltammetry. Theory and Application" (Springer, Berlin, 2007) with Macedonian Republic Award "Goce Delčev." Š. Komorsky-Lovrić was the Regional representative for Croatia in the International Society of Electrochemistry from 2009 to 2014 [14, 16].

Nowadays, there are several groups, which are developed from M. Branica's team, active in the field of electrochemistry at the Ruđer Bošković Institute. The investigations of *M. Mlakar*, *D. Omanović*, *V. Cuculić*, and *A. Penezić* are focused on the development and improvement of voltammetric methods for the analysis and speciation of trace metals, especially their interaction with natural organic matter. Also, there are focused on the automation of voltammetric analyses and advanced data processing with various software tools is an additional aspect of their research. *I. Ciglenečki-Jušić* and *M. Marguš* are focused on electroanalytical methods in environmental analysis and characterization of organic and sulphur compounds. The main research interests of *N. Ivošević DeNardis* are bioelectrochemistry of cells and vesicles, the application of complementary surface methods (electrochemical and atomic force microscopy imaging) in the characterization of soft particles and interfacial processes in seawater. N. Ivošević DeNardis is currently the Regional representative for Croatia in the International Society for Electrochemistry (2021-). *M. Plavšić* and *S. Strmečki Kos* study marine polysaccharides and proteins and their interaction with copper ions using voltammetry and chronopotentiometry. *B. Gašparović* is characterizing organic matter in seawater using an electrochemical probe. *S. Frka Milosavljević* is studying surface-active organic films in seawater and the atmosphere using voltammetry and electrochemical impedance spectroscopy. *D. Jadreško* is currently focused on examining the relationship between the structure and electrochemical properties of various biologically active compounds and their electrochemical characterization using voltammetric techniques. In collaboration with Ivana Novak Jovanović (Institute for Medical Research and Occupational Health), a new electrochemical method was introduced for determining the total antioxidant capacity of biologically active molecules based on their in vitro (re) activity in suppressing the formation of the electrochemically generated superoxide radical anion. *E. Bura-Nakić* is using different electroanalytical methods and Hg electrode in order to study influence of organic matter and redox conditions on the metal speciation.

Somewhat independently from other electrochemistry groups, *Višnja Horvat-Radošević* and *Krešimir Kvastek* successfully collaborated throughout their entire scientific career at the Ruđer Bošković Institute. By doctoral dissertation "Impedance of Ag/AgI electrode" defended in 1972, K. Kvastek made a significant progress in electrochemical experimentations of that time by measuring frequency

response of electrode impedance using a Wheatstone bridge. He was among the first who developed corresponding alghorithms for electrochemical data analysis and utilized them at the University Computing Centre (SRCE), founded in 1972 in Zagreb. Over the years, K. Kvastek and his coworker V. Horvat-Radošević, published a number of papers on impedance of different metals, glassy alloy, metal oxide, conducting polymer and carbon based electrodes. Some of their papers were methodologically oriented and devoted to corrections for either experimental artefacts, or possible time changing of electrodes during impedance measurements. V. Horvat-Radošević was the Regional representative for Croatia in the International Society of Electrochemistry from 2003 to 2008. Her former PhD student *Katja Magdić Košiček* is currently working at the Ruđer Bošković Institute on the topic of electrodeposition of thin films suitable for the determination and detection of various radionuclides, primarily alpha emitters.

The scientists who began their electrochemical career at the Faculty of Chemical Engineering and Technology and are now at the Ruđer Bošković Institute are *Željka Petrović*, who focuses on bioactive coatings for corrosion protection of dental materials. Furthermore, *Katarina Marušić*, who is working on the synthesis of polymeric nanocoatings by irradiation for corrosion protection, and *Mark Žic*, whose work is methodologically oriented and related to electrochemical impedance spectroscopy.

In 1960. Faculty of Chemistry and Technology, was established in Split with the initial involvement of professors from the Faculty of Technology in Zagreb. For this reason, many researchers from Split did their PhD studies at the Faculty of Technology (Faculty of Chemical Engineering and Technology) in Zagreb. From the very beginning, the Faculty offered a course in electrochemistry taught by *Stjepan Lipanović*. He received his PhD from the Faculty of Technology in Zagreb under the mentorship of Professor Lovreček with a subject related to nickel passivity. His future research also focused on the corrosion and passivity of metals, especially aluminium. *Njegomir Radić* (1943-) was also a student of B. Lovreček (PhD on non-stoichiometric metal oxides), who later worked in the field of electroanalytics, especially with potentiometric electrochemical sensors.

Today, at the Faculty of Chemistry and Technology of the University of Split, there are two groups working on electrochemistry. More precisely, these groups are in the Department of Electrochemistry and Materials Protection and the Department of General and Inorganic Chemistry. The Department of Electrochemistry and Materials Protection was founded in 1991, but in 1977/1978, a Laboratory for Electrochemistry was established at the same faculty. The Laboratory and the Department were founded by Jagoda Radošević. After laboratory establishment, the courses such as Electrochemistry, Construction materials and protection and Physico-chemical basics of direct energy conversion were introduced [17, 18]. When the Department of electrochemistry was founded, it included scientific and teaching staff: *Jagoda Radošević*, *Ljiljana Aljinović*, *Maja Kliškić*, *Mario Šmith*, and *Senka Gudić*. The professors currently working in the same department are S. Gudić, *Ladislav Vrsalović*, and *Ivana Smoljko*. The main attention of this group is paid to corrosion protection, oxide films, and anodic materials for Al-air batteries.

Jagoda Radošević (1937-) received her PhD from the Faculty of Science, University of Zagreb in 1976 under the supervision of Marko Herak, professor of analytical chemistry at this faculty. The main topic of her PhD thesis was not focused on electrochemistry, but in her further work, she dealt with electrochemical investigations. While conducting the PhD thesis, J. Radošević was employed at the Faculty of Chemistry and Technology of the University in Split, where she continued her teaching and scientific career afterwards. She studied the macromorphological properties of electrolyte deposits under natural convection, as well as the electrochemical properties of aluminium and its alloys and the possibilities of its corrosion inhibition. She holds a recognised patent for the scientific discovery "Aluminium Protector Anode." J. Radošević had a fruitful collaboration with Aleksandar Despić from the Institute of Chemistry, Technology and Metallurgy in Belgrade. In 2007, she was honoured by the University of Split with the title of professor emerita. During this time, she started a study of fuel cells together with Professor *Frano Barbir* at the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture at the University of Split.

A doctoral student of M. Metikoš Huković at Department of General and Inorganic Chemistry, University of Split were *Zoran Grubač* (1960-) (PhD thesis: "In-situ study of oxide and sulphide layers on bismuth," 1996) and *Slobodan Brinić* (1956-) (PhD thesis: "Study of Sb influence on Pb behaviour in sulphuric acid," 1996.). S. Brinić's scientific interest later shifted from passivity phenomena to electroanalysis and electrochemical sensors, on which he works together with *Marija Bralić* and her younger colleagues *Nives Vladislavić* and *Mario Buzuk*. Z. Grubač continued his research in the field of corrosion and passivity together with his collaborator *Ivana Škugor Rončević*, as well as in the field of energy conversion and electrocatalysis.

There was a small group dealing with electrochemistry at the Faculty of Food Technology, Department of Applied Chemistry and Ecology, J. J. Strossmayer University of Osijek. *Marijan Šeruga* (1947-) was the founder and head of this electrochemistry group at the Faculty of Food Technology. He received his PhD in Chemistry from the Faculty of Technology in 1977 ("The investigations of physical and electrochemical properties of some aluminium alloys") under the supervision of Prof. N. Ciković. He continued his postdoctoral training at the University of Manchester, Institute of

Science and Technology under the supervision of Professor G.C. Wood and Prof. G.E. Thompson (1979.) in the field of the passive films on aluminium in phosphoric acid solution. He collaborated with many well-known electrochemists: M. Metikoš-Huković in 1987–1997 (the study of passive films on tin); Prof. Klaus Wandelt at the Institute of Physical Chemistry, University of Bonn, Germany, in 1996/1997 (study of ultrathin films on tin); Prof. Kenichi Shimizu at Keio University, Yokohama, Japan, in 1998 (Study of the structure of passive films on aluminium); Prof. Ana Maria Oliveira Brett, University of Coimbra, Portugal in 2007/2008 through the research of PhD student Ivana Novak with Prof. Brett; and with Prof. Jan Labuda at the Faculty of Chemical and Food Technology, Bratislava, Slovakia in 2012/2013 through the part of PhD student Ivana Tomac's thesis. M. Šeruga was the regional representative for Croatia in the International Society of Electrochemistry from 1997 to 2002.

The members of the M. Šeruga's group were *Damir Hasenay*, *Martina Medvidović-Kosanović*, *I. Novak Jovanović*, and *Ivana Tomac*. M. Medvidović-Kosanović works now at the Department of Chemistry and her work is focused on voltammetric techniques (cyclic, differential pulse and rectangular voltammetry), EIS, study of biologically active compounds (flavonoids, Schiff bases, and their metal complexes) and studies of interfacial processes at the electrode surface. I. Tomac works at the Faculty of Food Technology and her work is focused on the development of techniques for the determination of biologically active compounds and metals in real systems and the development of electrochemical biosensors. I. Novak Jovanović works at the Institute of Medical Research and Occupational Medicine, Zagreb. Her research focuses on the development and evaluation of electrochemical methods for the determination of bioactive compounds in real samples, the study of electrochemical oxidation/reduction mechanisms of bioactive compounds by voltammetry, and the study of antioxidant properties of naturally occurring antioxidants.

Milan Sak Bosnar (1947–2017) [19] worked at the Department of Chemistry, J. J. Strossmayer University of Osijek, since 2005. His scientific work was mainly focused on electrochemical surfactant sensors. During his career at the Department of Chemistry he had a several projects and many PhD students worked under his supervision. M. Medvidović-Kosanović joined his group in 2008, where she obtained her PhD under his supervision.

Electrochemists from Croatia were actively participating at many scientific conferences, especialy "Yougoslav Simposia on Electrochemistry" that was initiated by M. Karšulin and held every second year (1969–1991) (Figs. 1, 5). Two Annual meetings (22nd and 32nd) of International Society of Electrochemistry (ISE) were organized in Dubrovnik 1971, and Cavtat 1981. Eight International Summer conferences "Chemistry of Solid/Liquid Interfaces" (1969–1989) and the International Symposium "Electrochemistry of Interfacial Phenomena" (1975) were organized by V. Pravdić, ZIMO and Ruđer Boskovic Institute. After establishment of Croatia the new conference series was founded by Ljerka Duić, "Croatian Symposium on Electrochemistry" (1998–2006), which was organized four times by Croatian Society of Chemical Engineers and Croatian Chemical Society. Afterward, V. Horvat-Radošević and Z. Mandić were involved in the initiative committee for the establishment of "Regional Symposium on Electrochemistry of South-East Europe," which later grew into the Association of South-East European Electrochemists (ASEEE, www.aseee.eu) as a unique regional voluntary framework bringing together scientists involved in fundamental and applied electrochemistry and its applications in different fields. The ASEEE conferences have been held continuously since 2008 (Croatia, Red Island 2008; Serbia, Belgrade 2010; Romania, Bucharest 2012; Slovenia, Ljubljana 2013; Bulgaria, Pravets 2015; Hungary, Balatonkeneze 2017; Croatia, Split 2019; and Austria, Graz 2022). The young members in Croatia are active

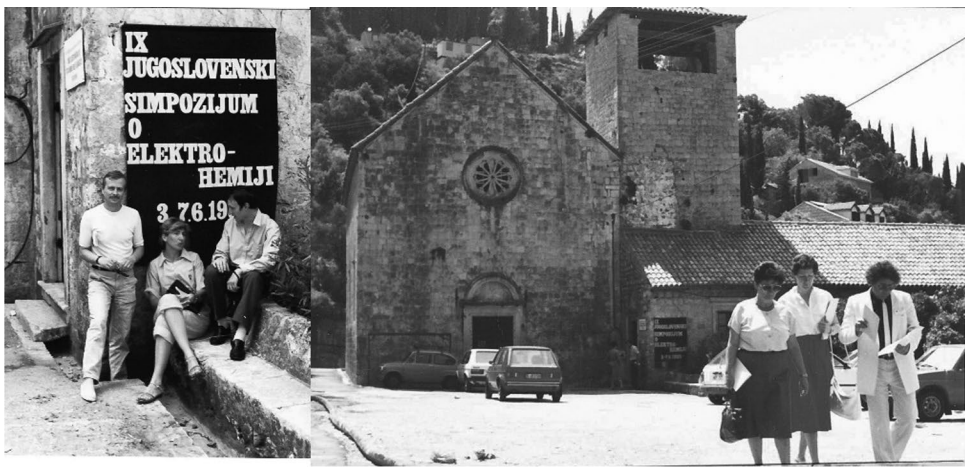

Fig. 5 Participants in front of the Institute of Corrosion Research and Desalination where Yugoslav conference on electrochemistry took place in 1985, Dubrovnik

in organising "ISE Satellite Student Regional Symposium on Electrochemistry," which takes place once a year since 2011. This meeting is supported by International Society of Electrochemistry.

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