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History and Perspectives from My Contribution to the Development of Electrochemistry in Mexico

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Abstract. Dr. Yunny Meas tells us about his participation in the development of electrochemistry in Mexico, from his beginnings as a guest researcher at CINVESTAV in 1978, through a short period at UNAM and a prolonged period at UAM-Iztapalapa, to the current creation and maturation of CIDETEQ. He relates his professional experiences with each stage's political and economic conditions, which taught him how to focus his R&D lines to help the sustainable growth of the region and the country.
Keywords: Electrochemistry, electrodeposition, water treatment, Mexican Society of Electrochemistry, CIDETEQ.

Resumen. El Dr. Yunny Meas nos relata su participación en el desarrollo de la electroquímica en México, desde sus inicios como investigador invitado en el CINVESTAV en 1978, pasando un periodo corto en la UNAM y un periodo más largo en la UAM- Iztapalapa, hasta la creación y maduración actual del CIDETEQ. Relaciona las experiencias profesionales con las condiciones políticas y económicas de cada etapa, que le sirvieron de lecciones para aprender a enfocar sus líneas de I &D para ayudar al crecimiento sostenible de la región y del país.
Palabras clave: Electroquímica, electrodeposición, tratamiento de agua, Sociedad Mexicana de Electroquímica, CIDETEQ.

Education

After completing my studies in France, which went from elementary school to an engineering degree and Ph.D. at the National Superior School of Electrochemistry and Electrometallurgy of the National Polytechnic Institute of Grenoble, I came to Mexico as a part of a Mexico - France cooperation program, whose mission was to help in the consolidation of an electrochemistry laboratory and assist in the training of graduate students who were in this laboratory. The essence of this mission, which focused on both research and teaching, I have kept it my own in all the following years and up to date.

On research and teaching

From 1978 to date, I have lived through several very different periods, each of them has had its own challenges:

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First period

From 1978 to 1981: I worked at the Center for Research and Advanced Studies (CINVESTAV) and the National Autonomous University of Mexico (UNAM) on topics related to solar energy: from 1978 to 1980, I collaborated on photoelectrochemistry on the CdTe semiconductor that the physics department at CINVESTAV had synthesized. I liked the topic; it was new then and aligned with Mexico's enormous solar radiation resource. Furthermore, I had worked on solid electrolytes in my doctoral thesis, and I knew solid-state physics, so I could quickly understand and guide some graduate-level students effectively. During this period, CINVESTAV invited me to teach one-week intensive classes on Electrochemistry at provincial universities. It was an extraordinary experience that allowed me to become familiar with other institutions. From these courses, we wrote some notes entitled "Bases of modern electrochemical kinetics" and "Electrochemistry of semiconductors," which are still valid today and are consulted by students. [1,2]

Later, I continued working in the "Solar Energy Department of the Materials Research Center of UNAM." There, we developed various technologies to produce selective surfaces for solar thermal collectors. That year, it was a great source of satisfaction to witness that two undergraduate students could electrodeposit several tens of square meters of black chrome in an electroplating workshop for the air conditioning system that colleagues from the Solar Energy Department had designed and built for the laboratories at Cerro Prieto, Mexicali, Baja California. With the use of modern TRL terminology, we went from TRL 3 to TRL 6 in about three years. On this topic, we completed three bachelor's and two master's thesis and several publications [3-6]

Second period

In 1981, I started working at the Autonomous Metropolitan University (UAM-Iztapalapa). As of February 1982, the country entered a period that surprised me enormously. There was a very high devaluation and inflation; no more dollars were in the banks, which led to the closing of imports. The consequence was a drastic decrease in my salary, and the budget that my institution had committed to buy some equipment remained at zero. Therefore, we had an enormous challenge to quickly find the means to do research and finance materials and scholarships for students. Fortunately, the university paid a few hours to students who worked as assistants in some classes and laboratories, and several colleagues let us use their equipment. Therefore, it was essential to establish a supportive and collaborative guild to move forward. We held several academic meetings among the few electrochemists that existed then. The opportunity to formalize the guild, Sociedad Mexicana de Electroquímica (SMEQ), arose from the initiative to organize the VI Reunión Latinoamericana de Electroquímica y Corrosión (VI RLEC) in 1983 in Oaxtepec, Mexico.

At that time, I started the research topic on electrocatalysis because there was a fuel cell development program in Mexico. Therefore, the subject was oriented to ruthenium-based electrocatalysts, particularly platinum-ruthenium, because the neighboring laboratory could synthesize them. On this topic, we developed the novel technique of underpotential deposition, with which we could deposit sub-monolayers of atoms of another metal, such as copper, on ruthenium surfaces for surface and active site characterization, as well as other metals to study their electrocatalytic effects. [7,8,9] This topic was developed by our first Ph.D. student, Dr. Marco Antonio Quiroz, and later by different Ph.D. and M.Sc. students at UAM.

We also investigated and developed titanium electrodes coated with ruthenium oxide and other metal oxides in electrocatalysis. Again, this is a topic in which several Ph.D. and MSc students participated, with coatings that we have applied in different processes, both in electrochemical synthesis and electroplating, as well as in the coating of anodes for corrosion protection systems.

We initiated relationships with the industry and started research project contracts. We had to learn by doing. These contract research projects allowed us to fund materials, reagents, and student scholarships. Another topic of interest was the deposition of alloys for different applications. During this second period, the objective was the substitution of imported products.

Third period

In 1988, the country began to open-up, particularly to establish a North American free trade agreement. This commercial opening also brought challenges for companies that had to be more competitive and had to comply with the environmental norms that were becoming stricter. Around this time, we supported small, medium, and large companies such as Condumex, and Mexichem, increasing their technological

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competitiveness, adapting technologies to improve the quality of their products, and complying with environmental regulations.

After several years of management, CIDETEQ was created in 1991 to link researchers with industry through R&D projects and technological services as well as to train human resources through its graduate programs and special courses. I was honored to be appointed as its first director, a function in which I have served with all my energy and heart for 9 years. After studying the needs of the companies in Queretaro, where there was a strong metal-mechanical industry but also water scarcity, we defined that at CIDETEQ, we had to develop the capabilities to support the topics of coatings and water treatment. We worked on various zinc alloys and developed additives for electrodeposition. As a result, several Ph.D. and M.Sc. thesis were completed, as well as several publications, we cited here some representative publications. [10-22] We have also developed a strong relationship with the electroplating industry, with small and medium companies of CANACINTRA, and to date, with several industrial clusters, such as aeronautical and automotive. Regarding water treatment, we have developed research and technologies to make water drinkable and treat wastewater for reuse or recycling. In this case, we provide solutions to industries in different sectors, including automotive and aeronautics, food, livestock, textiles, and paper. During this period, we conducted several research and technological developments on coating and water treatment systems.

Recent and current period

For the past decade, at CIDETEQ, we have sought to participate in projects that meet the sustainability objectives set by the United Nations (ONU). We have also initiated an orientation of our work with the motto: "Knowledge and Clean Technologies for Social Welfare. “This new orientation prepared us for the current transformations towards a more collaborative and, above all, more humanistic dynamic. We have been working to ensure our projects have a more significant social impact for several years. In the last four years and for the near future, we have participated and will continue to participate in projects of strategic national programs (PRONACES). We have experienced this thanks to our ability to collaborate and our openness to work in an interdisciplinary manner.

History of the evolution of the academic part of electrochemistry and perspective

When I arrived in Mexico in 1978, I was fortunate to meet six electrochemical researchers. Each of us with different academic backgrounds graduated in different countries and on different topics. We were working in various institutions (at that time, these colleagues were from UNAM, CINVESTAV, and National Institute of Electricity and Clean Energies (INEE, ex IIE). We occasionally met because we did not have the communication facilities we have now, only mail and telephone; later came fax, emails, messages, and videoconferences; everything was done on paper and writing by hand or typewriter. We had frequent seminars with our students and colleagues who wanted to participate. It has always been and still is with much enthusiasm and pleasure to see each other, share, and contribute our knowledge.

The formal formation of the electrochemists’ guild in Mexico came about thanks to the opportunity we had to organize the VI Latin American Meeting of Electrochemistry and Corrosion in Oaxtepec Mexico (RELEC). We had the chance to meet colleagues from Argentina, Brazil, Chile, Colombia, and Panama. The most important and consolidated group was from Argentina, whose researchers later came to give workshops in their specialties. It was also the beginning of international collaborations with countries such as Germany, the United States, France, Spain, England, and Italy. These international collaborations later expanded to other European, Asian, American, and Oceanic countries.

For the organization of the VI RLEC 1983, we had to formalize the small guild. I had the honor of carrying out this formalization of the Mexican Society of Electrochemistry (SMEQ) and becoming its first president. The creation of SMEQ was based on the principles of solidarity, fellowship, and collaboration to fulfill its mission; thus, our needs and strategies for the consolidation and growth of the SMEQ were:

√ Generate and consolidate the guild to strengthen collaborations and hold meetings to exchange experiences about our work and exchange challenges and good practices in teaching and research.

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√ Establish international relations to strengthen our research groups in the different specialties and exchange teachers, researchers, and students (through internships and postgraduate studies) at the national and regional (participation in the creation of SIBAE - Iberoamerican Society of Electrochemistry - where I was president), and international levels (with the involvement in the congresses of the "Electrochemical Society (ECS)" and the "International Society of Electrochemistry" (ISE), as well as participation in their committees and organization of congresses of ECS (publication committee) and ISE (executive committee as vice-president).

√ To provide further visibility to the Mexican Electrochemical research community through organized congresses and publications; for example, Mexican and Latin American researchers and students significantly participated in the ISE congress in Queretaro.

The SMEQ has grown in the number of members (more than 450) and specialty areas. All colleagues participated very enthusiastically in its consolidation and growth, caring for collaboration, fellowship, and solidarity. The number of Mexican federal entities where electrochemists are located went from 3 in 1983 (we did not know if there were more due to the lack of internet communication) to 23 in 2022, thanks to the great work of all colleagues and students in consolidating the electrochemistry guild.

Current topics in the areas we are working on and the near future

In 1984, our research topics were related to materials and processes. We were researching the understanding of the mechanisms of electrodeposition of metals and alloys of interest, as well as their production for the national industry, as well as the obtaining of electrocatalytic electrodes and processes to produce different products of national interest and for corrosion protection systems and fuel cells.

Since 1991, at CIDETEQ, we have expanded the topics to energy and environment, particularly for water treatment. It is worth noting that our challenge has been and continues to be performing R&D from TRL 1 to 6 and, in some cases, to perform installations at the industrial level in companies. Therefore, we had to develop various capacities and competencies in this regard.

In recent years, the health area was created where work focused on developing sensors for detecting molecules related to diseases such as cancer, diabetes, and others.

Environment and water

The issue of clean water availability is becoming increasingly critical. Therefore, for researchers, a permanent issue must be addressed, from its potabilization, treatment for its conditioning in processes, and wastewater treatment for its reuse, recycling, or simply compliance with the corresponding standards. We have also focused on wastewater treatment for new polluting products such as medicines. The overexploitation of groundwater causes the lowering of its level and the increase of its hardness, as well as concentrations of As and F in several regions of Mexico. The availability of groundwater resources is also drastically decreasing. Therefore, it is necessary to find solutions to reuse or recycle water and care for and treat other sources, such as rainwater.

There are also many opportunities for developing sensors for the environment and water. Many new pollutants, such as pharmaceuticals, still need to be treated or analyzed quickly and economically. Another topic we have recently addressed in a PRONACES project is the replacement and treatment of glyphosate, which is widely used in agriculture. Researchers still face many challenges in addressing the social benefit of this environment and water issue.

Another critical issue currently at the environmental level corresponds to climate change. Although attention is focused on reducing greenhouse gas effects and we are working on some problems, there are still many challenges that electrochemists can contribute to their resolution.

Energy

On this topic, there are also many challenges. For example, the development of materials for the different components of batteries to make them more efficient, such as higher specific energy and power

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capacity. Currently, the focus is on Li batteries. However, from ore extraction to a battery, there is a long way where we can all find research and technology development opportunities. Also, the research opportunities for future batteries are not only Li but also other economic materials such as sodium and zinc in Mexico and aluminum in other countries. We often consider only electrode and electrolyte materials. Still, there are membranes, gaskets, casing, and secondary systems such as connectors, cooling, and other indispensable parts for the proper functioning of the batteries.

Health

R&D of microsensors of molecules related to the most critical diseases, such as cancer of different body parts, diabetes, and other molecules, are researched and developed. Considering the importance of the subject, the National Microfluidic Laboratory was created, which brings together several laboratories from different institutions in the country.

Materials

The subject of materials is closely related to the others. In this area, the focus has been to include or synthesize through new processes or nanometric materials (such as graphene), multifunctional materials, for example:

- New electrocatalysts
- New coatings (alloys or multilayers) with improved optical properties
- Special physical properties
- More excellent protection against corrosion or self-curing

Prospects for the future

In the educational sector and academia

Due to the increase and acceleration in generating information from research and technological development, pedagogical methods based on memorizing information still need to be updated. A lot of information can be found on the Internet. But, of course, we still teach the fundamental concepts. Under these current considerations and the future medium-term outlook, I agree with the pedagogues who suggest that we help our students to have, as Yuval Noah Harari summarizes: "critical thinking, communication, collaboration, and creativity. .... Emphasize the abilities to adapt to change, learn new things, and maintain mental balance in situations with which we are unfamiliar... We need not only to invent new ideas and products, but above all, we need to reinvent ourselves repeatedly".[23]

Therefore, in addition to conducting experiments and generating information, we should teach our students to understand the problem and to create the methodologies and strategies that we will use to conduct research, technological development, and innovation so that they can face the future successfully. Our professional duty is to teach and train them to acquire these capabilities.

The thinking mechanisms for generating ideas for new research topics seem challenging to understand because it is not only through a rational methodology. Developing an original, novel issue that does not correspond only to an improvement or a deepening of the same topic is more a process of creativity. In our case, these ideas arise from different experiences.

In our experience, project topics have arisen through needs or problems we have detected at congresses, talking with colleagues working on the same issues, or different topics. They also emerged through bibliographic reviews or the study of a topic or technology's state of the art, meetings with industrialists to learn about their needs, and recently with communities in the social sector to learn about their needs.

Liaison with the social, industrial, and governmental sectors

We are convinced that the strategies to follow depend on knowing the problems, needs, frustrations, and desires of the people in the different sectors we are serving to seek solutions that provide these people with a more significant benefit for their well-being and happiness,

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With the public and social sector, we recommend participating in Mexico's strategic national programs and the different international calls for proposals. Also, at a regional or local level, participate in the various social councils or industrial clusters to learn about the different sectors' challenges, problems, and opportunities.

The recommendation would be that, to consolidate our own perspective, we need to "*get out of our laboratories*" and meet with the people of the sector we want to serve, to discover and understand their problems, needs, frustrations, and desires and then seek and propose solutions that generate happiness for them. *In conclusion, we must seek, detect, and transcend our mission in science.*

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