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A SHORT HISTORY OF ELECTROCHEMISTRY IN INDIA

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Abstract

Except for some vague reference to a claim about a battery some 7000 years ago, any discussion on the history of electrochemistry in India should begin with the early twentieth century work by J.C. Ghosh on the conductivity of strong electrolytes. Thereafter, it is post-independence history during which the Central Electrochemical Research Institute and the Indian Institute of Science steered the course of electrochemical research and education in the country. Prominent among the architects of electrochemical science and technology in India were Doss, Amulya Reddy, and the 'Bangalore trio' of Sathyanarayana, Rangarajan and Rajagopalan. Major beneficiaries of electrochemical research include sectors such as the railways, space, petroleum and the chlor-alkali industry. Today, electrochemistry is a major area of research at several pockets across the country. At least four major professional societies are actively involved in the promotion of electrochemical science and technology in India.

Key words: Agastya battery, Bangalore trio, Chlor-alkali, Electrochemistry, Electrodeposition, Electro-organic chemicals, Industrial electrochemistry, History of polarography

1. Introduction

India, the land of the Vedas, has a proud history of scientific research in fields as varied as astronomy, botany, chemistry, mathematics, medicine and metallurgy. Nalanda University, which was once the Harvard of the world, is sought to be resurrected to its old glory. Knowledge was passed on by word of mouth from the *gurus* (teacher) to the students, and any documentation in the form of stone engravings and palm leaf writings was left to the vagaries of weather and warring men. Such being the record-keeping in India, the authors are skeptical, yet tempted, to begin this article with a discussion on the Agastya battery, claimed to be the oldest battery and the oldest manifestation of electrochemical knowledge. *Agastya Saṃhitā*, a Sanskrit text of *ca*. 5000 BC, describes a method of making a battery (with copper as cathode and zinc amalgam as the anode) and talks of splitting water into oxygen and hydrogen[1]. Until about a century ago, scientific research in India, unlike in the West, was the domain of a selected few with a certain pedigree. Even in the just-independent India of the 1950s it was more of an oddity of human endeavor than a profession. Thus, it is no wonder that there is hardly any documentary evidence on how electrochemistry evolved in India. Electrochemistry as we know today is a new science that took roots at the turn of the 19th century in Europe. Its percolation into other parts of the world was gradual, first into physical chemistry syllabi and then as a practising science.

Initially, small pockets of activities emerged in centers of advanced learning such as the Indian Institute of Science (IISc) and Calcutta University before the fever caught on to other places. Most of the initial works were as enabling research such as for determining thermodynamic parameters, and mostly involved measurements of e.m.f. and conductivities. Among the most notable electrochemists of pre-independence India was J.C. Ghosh. His postulates that all ions in

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strong electrolytes are not free to move owing to the influence of electrical charges and that it is only the *mobile ions* that contribute to conductance placed the theory of strong electrolytes on a permanent footing[2]. He proposed that the 'active' proportion of the electrolyte could be determined purely from electrical data, without invoking the law of mass action. His work won appreciation from stalwarts such as William Bragg, G.N. Lewis, Walter Nernst and Max Planck. His postulates formed the basis of the well-known Debye-Hückel theory of strong electrolytes. But Partington's criticism[3] of his theory led Ghosh to decline his name being proposed for election as an F.R.S[2]. In fact, Partington had made an arithmetical blunder that enabled Ghosh to rebut the criticism, but Partington still stuck to his conclusions[4]. In 1937 Ghosh succeeded Sir C.V. Raman as director of IISc. His ten years at the institute saw electrochemistry being established as a major branch of scientific study in India. Ghosh was knighted in 1943 for his services to Indian science and industrialization[5]. The real push, however, had come with the invention of polarography, the only electroanalytical technique to have won a Nobel Prize (Jaroslav Heyrovsky 1959). The fever caught on in India, where R.S. Subramanya spearheaded a school of polarography at IISc. There was also a parallel school at IISc on electrodeposition led by T.L. Ramachar. Hereabouts, philanthropist Alagappa Chettiar dreamt of a national research institute solely dedicated to electrochemistry. That he did it at a time when electrochemistry was relegated to the flip-side of physical chemistry courses in the universities speaks volumes about his vision and foresight. Today, the institute he founded, the Central Electrochemical Research Institute (CECRI), is synonymous with electrochemistry in India.

2. Central Electrochemical Research Institute

K.S.G. Doss steered CECRI in its formative years and fostered both fundamental and industrial electrochemistry in India and greatly influenced the people who practised it [6]. He also pioneered wetting phenomena, a.c. effects on adsorption and electrode kinetics. It was Doss who introduced the techniques of tensammetry (independently of Breyer) and the redoxokinetic effect, now termed faradaic rectification. The impact of these techniques in adsorption studies, kinetics of fast reactions, and electroanalysis of trace metals is well known. His interests spanned a wide range of topics from fundamental aspects such as potential of zero charge and electrochemical oscillations to industrial problems such as zinc-air batteries for the Indian Railways. In 1975, the international electrochemical community honoured him by publishing a Festschrift of the *Journal of Electroanalytical Chemistry*.

Over the years, CECRI has blossomed into a premier center for electrochemical science and technology in Asia. Its contribution to the Indian industry is tremendous. Mention must be made of the titanium substrate insoluble anode for the chlor-alkali industry, a brainchild of H.V.K. Udupa. The technology has led to millions of dollars in terms of foreign exchange savings to the nation. Other technologies of note include those related to corrosion control (as reflected in the Pamban bridge, for example), duplex coating for the chlor-alkali industry and polymer electrolyte membrane fuel cells. CECRI also has set up of tropical corrosion testing centres in order to generate a corrosion map of the country. Other success stories may be cited in areas such as electro-organic synthesis (especially between 1960 and 1980) and electrochemical perfluorination. These inventions are supported by international patents and a host of industries benefited from processes related to electrochemical preparation of compounds such as calcium gluconate, glyoxilic acid, succinic acid and camphor. Similarly, several electrometallurgical processes such as those for sodium, magnesium and calcium developed at CECRI were a boon to the defence and atomic energy sectors.

Today, CECRI works on a gamut of problems covering all facets of electrochemical science and technology: corrosion science and engineering, electrochemical materials science, electrochemical power sources, electrochemical pollution control, electrochemicals, electrodics and electrocatalysis, electrohydrometallurgy, electropyrometallurgy, industrial metal finishing, nanoscale electrochemistry and electrochemical instrumentation. Agencies that tap CECRI's expertise include small and big private industrial houses as well as government agencies such as atomic energy, defence, environment, space, surface transport, and ocean development. The institute also grooms a future generation of electrochemical engineers through its BTech program in chemical and electrochemical engineering.

3. The Bangalore Trio

The achievements of scientists at CECRI, however, do not belittle the 'Bangalore Trio' whose schools were fountains of a plethora of theoretical and experimental electrochemical innovations. The trio of S. Sathyanarayana (IISc), S.K. Rangarajan (IISc and National Aerospace Laboratories, NAL) and S.R. Rajagopalan (NAL) turned Bangalore into a Mecca of Electrochemistry in India. All the three had their initial grooming at CECRI. Sathyanarayana etched himself in India's energy profile through his contributions such as space-quality batteries for the Indian Space Research Organization (ISRO), magnesium-manganese dioxide batteries for the Defence, and anodes for ammonium perchlorate electrolytic cells for ISRO. His less well known works include kinetics of corrosion of passive metals, absolute values of instantaneous corrosion rates by Faradaic rectification, polarographic maximum of the third kind, development of an alkaline iron electrode and state-of-charge determination by electrochemical impedance measurements. Rajagopalan was the architect of a host of industrial electrochemical processes for the NAL, where his pioneering work on electroforming and electromachining of intricate machine parts is part of the electrochemical folklore. His other notable studies include chemical modification for trace analysis and electroless plating. Rangarajan was foremost an electrochemist, but was also an unusual theorist, a philosopher, a poet and a mathematician. His unified approach to modeling interfacial phenomena at the macro, molecular, and electronic levels has had tremendous impact on theoretical and applied electrochemistry. Specific mention must be made of his contributions in special functions and mathematical analysis, systems analysis, inverse problems, superoperator formalism and Green functions, Pade approximations and intuitive analysis, quantum electrochemistry and many-body theory, Faradaic rectification, electrical double layer, electrochemical impedance, non-linear relaxation techniques, electrocrystallization, phtoelectro-chemistry, porous electrodes, current distributiona and roughness, and accelerated Tafel plots. K.S.G. Doss, the first director of CECRI, described Rangarajan as his most important discovery!

4. Indian Institute of Science

The moving force at IISc in the 1970s was the towering Amulya K.N. Reddy, whose two-volume magnum opus, *Modern Electrochemistry*, co-authored with J.O'M. Bockris, was a gamechanger in the way it projected electrochemistry as a lively trans-disciplinary scientific pursuit. In describing his book, Reddy said, "the ecstasy consisted of my discovering the electrochemistry for myself, being excited about what I learnt and communicating a fresh account of the learning." His research work centred around growth and structure of electrodeposits and *in situ* optical studies of anodic films. In 1974, still in his early forties, he burnt bridges with electrochemistry when he began asking questions on the inequalities in Indian society, and the role of technology and technologists. His valiant shift from electrochemistry to rural technology and sustainable development can be traced to his autobiographical article 'The Making of a Socially Concerned Scientist: Personal Reflections of a Maverick' (1973).

Latching on to the momentum generated by architects of nation-building such as Reddy, Sathyanarayana and Rangarajan, their students are now steering the course of electrochemical research in institutions such as IISc, CECRI, ISRO, IIT-Madras, Delhi University, Institute of Mathematical Sciences and Bharat Electronics Limited, not to mention those in the industry and those who migrated overseas. New torchbearers have emerged at IISc to continue the legacy of Sathyanarayana and Rangarajan.

5. Other Centers

Other forerunners of electrochemical activity in the country include the Institute of Science (electrocapillarity, fundamentals of adsorption); Bhabha Atomic Research Centre (polarography, corrosion); Indira Gandhi Centre for Atomic Energy (high temperature corrosion); Tata Institute of Fundamental Research (coulometry, electrochemiluminescence, electrobioluminescence, laser interferometry, conducting polymers, fuel cells, photoelectrochemical solar cells); Indian Institute of Technology-Bombay (corrosion engineering); Indian Institute of Technology-Madras (electrocatalysis and electrolyte solutions); and Banaras Hindu University (corrosion). The list is not complete as numerous other pockets of electrochemical excellence such as Delhi University, University of Rajasthan, University of Pune and Aligarh Muslim University are not covered in this article. Electrochemical equipments until two decades ago were beyond the reach of ordinary researchers, which drew in a number of electronics and instrumentation people especially at the IITs, IISc, NAL and CECRI.

6. Concluding Remarks

The Indian electrochemical community is mainly affiliated with three professional organizations: the Society for Advancement of Electrochemical Science and Technology (SAEST), the Electrochemical Society of India (ECSI), and the Indian Society for Electroanalytical Chemistry (ISEAC). Membership in these societies is largely confined to professionals working in India, and this community felt a need to extend its reach outside of the country. In December 2010 the Electrochemical Society (USA) accorded formal recognition for an ECS-India Section. More and more Indian electrochemists adorn editorial boards of international electrochemistry journals. Their names also figure in the editorial boards of journals devoted to materials science, solar energy, etc., reflecting the reach of electrochemistry as a transdisciplinary subject. If international recognitions continue to pour on the electrochemical community in India, the credit must be laid at the feet of our teachers and mentors. They continue to be remembered like valiant soldiers whom the ex-General of the US Army Douglas MacArthur described thus: 'Old soldiers never die, they just fade away.'

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