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Prospects of Electrochemistry[①]

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It is indeed a privilege to have been invited to contribute to the "Vision" of the Chinese Journal of Electrochemistry, the first volume of which appeared in the year of the Xiamen meeting, on behalf of the International Society of Electrochemistry. We always remember the successful ISE meeting in Xiamen in 1995 and never forget the hospitality you showed us during the meeting. We would like to have the ISE Annual Meeting in China again in ten to fifteen years.

At the end of 1797, Alessando Volta (1745 - 1827) invented the pile, which consisted of the silver and zinc electrode separated by cardboard soaked in salt water, and sent a letter to the Royal Society of London March 20, 1800. This is the birth of electrochemistry and the initiation of the electrical age. Immediately after the invention of the "electric pile", a continuous - flow current provided by the Voltaic pile enabled water decomposition, metal plating, electrophysiology, isolation of new elements, and new theories on the nature of electricity and magnetism. The invention of the "Steam Engine" in 1765 initiated the Industrial Revolution but we had to wait 150 years to initiate the Second Industrial Revolution since Volta invented the "electric pile". During this period, electrochemistry played a very important role in the productions of primary industrial products. The last fifty years of the 19^{th} century was a golden age for theoretical electrochemistry. Four Nobel Laureates in Chemistry in the first nine years were electrochemists (J. H. van 't Hoff in 1901, S. A. Ahrrenius in 1903, H. Moissan in 1906 and F. W. Ostward in 1909).

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Electrochemical industries became less important with the development of the peterochemical industries in the 1950's. Electrochemical science, accordingly, went into a gloomy period. The invention of the "transistor" at Bell Laboratories in 1948 was the initiation of the Second Industrial Revolution. The developments in of "electronics" made a strong impact on electrochemical science and industry and they started blooming again in the1960's.

A little before the dawn of the new electronic age, the *Committe International de Thermodynamique et de Cinetique Electrochimique* (CITCE) was founded in 1949 in Europe. In 1971, CITCE changed its name to the International Society of Electrochemistry (ISE) to reflect the growth of the organization from a small committee to a large international society representing the worldwide community of electrochemists and ISE became a professional society. Unlike other professional societies, the creation of CITCE was an act of reason and faith. The officers of CITCE consciously attempted to create an atmosphere in which young participants would feel as much at ease as their elders. There was no requirement for publications and no stipulation that the communications be entirely original. The members of CITCE wanted the communications to express essentially the present state of the author's work, and for the authors to accept all the friendly and constructive discussion. It was also in this spirit that a "moral charter" was drawn up for CITCE. Many of the CITCE members have thought that international meetings are above all an opportunity to serve, to meet people of different backgrounds, and make friends with them. This was the key to the considerable scientific and moral success of CITCE. The members of ISE still benefit from the good heritage of CITCE.

Individuals, industrial companies, non-profit organizations and learned societies may become members of ISE. At present ISE has 1,058 individual, 45 Corporate Sustaining, and 29 Corporate members from more than 61 countries. Those individual members from European countries are 63 % (France: 85; Germany: 78; Italy: 63; Spain: 48; UK: 38; Switzerland: 34; Russia: 30; Greece: 29; Portugal: 20; Poland 23; Hungary 20 and others), 10 % from North America (USA: 92; Canada: 14), 7.2 % from South America (Argentina: 26; Brazil: 26; and others) and 17.2 % from Asia (Japan: 128; China: 20; Korea: 20; and others). The membership of ISE in China is increasing (9 members in 1993 and 20 in 1997). I also noticed that contribution of electrochemistry papers from China to International Journals is increasing dramatically since 1996.

Among new trends in electrochemical science and technologies, I would like to mention several topics, which are related to the activities of ISE.

Interfacial Electrochemistry: Most of the newly developed techniques of surface science have been carried out in ultrahigh vacuum and are not applicable to electrochemical systems, in situ. Recent developments of spectroscopic techniques (UV-vis, IR, Raman, X-ray, NMR, and

ESR) and scanning probe microcopies (electrochemical STM and AFM, near field microscope) enable us to characterize surface structures of metal electrodes, electrode surface layers (adatoms, adorbed ions and molecules, metal oxides, self - assembled monolayers, polymer layers, etc.). The molecular level studies of electrode interfaces are one of the frontier subjects of modern electrochemical science and will accelerate the rate of nanoscale electrochemistry.

Batteries: A growing demand for small portable power supplies for electrical and electronic appliances resulted in the development of high energy and reliable power sources of different types and sizes. An exponential growth in energy utilization and in the world population creates serious environmental problems. The developments of emission - free energy sources such as fuel cell power plants and electric vehicles are important developments for the 21^{st} century. For non - rechargeable and rechargeable batteries, new electrodes (both anode and cathode) and separator materials enable the construction of high performance (high energy density, heavy duty, and long life) batteries. Operating temperatures of fuel cells range from room temperature to about 1000 ℃. The impurity tolerance of noble metals as electrocatalysts is small at lower temperatures and is improved as the temperature is increased. At higher temperatures, noble metal catalysts are not required but durability of cell and electrode materials is an important subject. Regardless of the types of fuel cells, new or improved materials are the most important issues to further development. The electrolyte for the "Solid Oxide Fuel Cell", a high temperature fuel cell, is an oxide ion conducting ceramic and, fuel electrodes and connectors are electron - conducting ceramics. The structural components require gas tightness, and mechanical and thermal stabilities at high temperature.

Electrodeposition and Surface Treatment: Historically, electrodeposition of thin metallic films was widely used for decorative plating and corrosin protection. Preparation of tailored materials and structures on the submicron - to - atomic scale is the frontier of electrodeposition. Modern electrochemical instrumentation can control the deposition and dissolution layer by layer on an atomic scale under mild atmospheric conditions and precise process control is possible. Three - dimensional quantum dot structures are electrodeposited atom - by - atom by using STM. It is possible to produce high quality superlattices as small as a few nanometers for both metallic and non-metallic systems. Electrochemical machining can provide high - speed fabrication of microcmponents at low cost with excellent precision at ambient temperature under environmentally benign conditions. Remarkable advancements have been made in magnetic recording media and recording heads by electrodeposition technology. Modern electrodeposition technology is blended with vacuum processing and finds increasing application in the electronic industries.

Tailored Electrode Materials: Besides noble metal electrocatalysts in fuel cell technology, various types of carbon materials, and electron and ion conducting polymers have been developed for batteries. The deliberate manipulation of an electrode surface structure with thin polymeric and monomolecular films, in which or at the end of which functional groups are attached, are a major area of chemically modified electrodes. New chemical, biochemical, electrochemical, and optical functions are created by chemical modification of the electrodes. The electrochemical quartz crystal balance allows simultaneous monitoring of mass change in the sub - nanogram range and current and enables the investigation of electrochemical reactions at electrode surfaces.

Electrochemical Sensors. Sensors have been widely used for the control of industrial processes, for monitoring environmental pollution, for medical diagnosis, and for controlling the performance of automobiles. There are many transducers for measuring the quantities of interest such as electrical or optical signals. The development of sensor technology based principally on transducer materials and, sensitive, selective, reliable and rapid detection of chemical or electrochemical reactions of interest at the surface of the transducer. Sensors operating at ambient temperature measure such quantities as electrode potential based on the Nernst equation or current based on Faraday's law. Gas sensors utilized porous metal oxides and the sensors detect combustible gases from a decrease in electrical resistance of the element.

Finally, I sincerely hope that the ISE can cooperate with the development of Electrochemical Sciences and Technologies in China and the success of your journal.