Fully charged

Professor Dr Mark E Orazem, President of the International Society of Electrochemistry, details the importance of the field and its increasing global cooperation…

Electrochemistry, associated with reactions and processes involving charged species, has a broad scope, encompassing aspects of chemistry and chemical engineering, materials science, electrical and electronic engineering, mechanical engineering, and civil engineering.

Applications

Electrochemistry plays an important, though often unappreciated, role in modern society. Roughly one-ninth of the chemical process industry is electrochemical. Chlorine, produced electrochemically from brine, is used in making plastics, solvents for dry cleaning and metal degreasing, textiles, agrochemicals and pharmaceuticals, insecticides, dyestuffs and household cleaning products. The process also creates sodium hydroxide, a strong alkaline chemical used in the manufacture of paper, textiles, soaps and detergents. Metals, such as aluminium, copper and magnesium, are refined using electrochemical processes.

Electrochemical products are also widely used by consumers. Batteries convert chemical energy to electrical energy through electrochemical reactions. The ubiquitous lead acid battery is used to start automobile engines or to provide energy for propulsion of small vehicles such as golf carts. Exceptionally high power and energy densities make lithium-ion batteries popular power sources for small devices, such as mobile phones, digital cameras and watches. While the development of mobile phones and portable electronics is generally attributed to progress in electronics, the recent progress in batteries has been an equally essential step.

Electrochromic rear-view mirrors, found in most automobiles, are electrochemical devices that reduce night-time glare from reflected headlights. This technology is also being used to replace window shutters in the new Boeing 787 Dreamliner and in business aircraft such as the new Hawker Beechcraft King Air 350i. Foils for electric razors are produced by electroforming, and electroplating is employed to deposit gold layers onto electrical contacts, to deposit copper interconnects in electronic circuits, to create silver-plated jewellery and tableware, and to make magnetic alloys for recording media.

Current research initiatives

Current areas of study include environmental, biomedical and electronic applications. Energy and infrastructure are two areas of special interest.

Energy

Advances in the area of energy will require development of new generations of batteries and super capacitors for energy storage and conversion. Fuel cells, in which chemical energy is converted to electrical energy, have applications in load-levelling in power grids, automotive propulsion and other local generation of electrical power. The chemical energy is stored outside the fuel cell, whereas, the chemical energy of a battery is contained within the battery. Thus, a fuel cell need not be constrained by the charge-discharge cycle of a battery. Lithium batteries are being developed as a replacement for the nickel-cadmium batteries used in hybrid vehicles and as a power source for a new generation of electric vehicles. Some common areas of research include exploration of new chemistries using cheaper and more plentiful raw materials, enhancing the power and energy density, increasing life cycle and ensuring safety.

Infrastructure

Infrastructure is the technical foundation for society – including roads, bridges and parking garages used for transportation; pipelines used for delivery of water and removal of waste; public and private airports; pipelines for the delivery of petroleum products and natural gas; and tanks for hazardous materials storage. All these infrastructures are subject to corrosion. Electrochemistry is the basic science that allows us to understand both corrosion and the technological solutions needed to prevent it. Cathodic protection, for example, can be applied to prevent corrosion of steel reinforcements in concrete and pipelines.

In the absence of appropriate measures of corrosion protection, essential structures may fail catastrophically. The collapse of the southern outer roof of the Berlin Congress Hall in 1980, only 23 years after construction, was attributed to corrosion. The single-span Ynys-y-Gwas Bridge in Wales collapsed in 1985 as a result of corrosion of longitudinal tendons at its segmented joints. The post-tensioned Melle Bridge, built in Belgium in 1956, collapsed

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in 1992. In this instance, the bridge had been inspected, load tested, re-waterproofed, declared adequate and restored to service just two years prior to its collapse. More recently, the Santo Stefano Bridge in Italy (1999) collapsed due to similar corrosion related failures. The collapse in 2000 of the Lowe's Motor Speedway footbridge in North Carolina was attributed to corrosion. In each of these cases, the corrosion that caused the structural failure was hidden from view. The annual direct cost of corrosion in the infrastructure and utility sectors was estimated in 2001 to be over $70bn in the USA alone.[1] Approximately 15% of the bridges in the USA in 2001 were reported to be structurally deficient, primarily due to corrosion of steel and steel reinforcement. The asset replacement value of the oil and gas transmission pipeline system in the US is $541bn, and understanding and managing corrosion is critical to controlling the life of this asset. Some key issues involve the development of new ways to detect the onset of corrosion and new methods to mitigate it.

Challenges facing the electrochemical community

The aforementioned efforts share common research challenges. Advances in energy technologies, such as batteries and fuel cells, require new materials and/or chemistries. Development of new materials and chemistries is also important to maintaining infrastructure. The challenge is to find materials that will provide the desired performance at an acceptable cost.

A special challenge for batteries is that the goal of achieving high energy density requires storing a large amount of chemical energy in a small volume. Loss of control can have disastrous and even explosive consequences. Thus, improvements in performance must be achieved while maintaining safety. Advances in the area of infrastructure require development of new sensing technologies capable of detecting corrosion inside concrete structures, as well as means of halting or reversing the material degradation.

From a broader perspective, research funding for electrochemistry today is driven by the desire to achieve technological goals and products. There is a need to enhance support for fundamental research in areas that do not directly lead to a product but may support multiple technological goals. While some areas, such as nanotechnology, have received adequate funding, funding should be expanded for other areas, such as the development of the novel experimental and modelling tools needed to understand the phenomena associated with corrosion and energy systems.

Role of international cooperation

International professional societies have become increasingly important because valuable contributions in electrochemical research today are coming from many countries. The NSF reports that the US share of science and engineering research journal publications declined from 36% in 1988 to 20% in 2008. During the same period, Japan's share declined from 12% to 7%. This decline was accompanied by an increase in the number of articles published by the rest of Asia from 7% to 30%, with China producing nearly half (14%) of these articles by 2008.

The work has become more internationally collaborative, as the percentage of science and engineering research articles with authors from more than one country increased from 8% in 1988 to 22% in 2007.[2] The need for an international forum for electrochemical research is met by the International Society of Electrochemistry (ISE), a non-profit organisation based in Lausanne, Switzerland, which now comprises about 3,000 members from more than 70 countries. Annual and topical meetings are held throughout the world, with meetings in Europe, Asia, Australia, North and South America, and, soon, in Africa. The society journal 'Electrochimica Acta' provides a high-impact-factor vehicle for sharing ideas and results.

[1] Koch G H, Brongers M P H, Thompson N G, Virmani Y P, Payer J H, Corrosion Cost and Preventive Strategies in the United States, CC Technologies Laboratories (Dublin, OH) and NACE International (Houston, TX), 2001

[2] National Science Board. 2010, Science and Engineering Indicators 2010, Arlington, VA: National Science Foundation (NSB 10-01)

Professor Dr Mark E Orazem
President
International Society of Electrochemistry
Tel: +41 (0)21 648 39 75
info@ise-online.org
www.ise-online.org