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EDITORIAL

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Solid state electrochemistry ≡ electrochemical physics: genesis and scope

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Michael Faraday was not only the father of quantitative electrochemistry, he was also the first solid state physicist: in 1833 he showed that silver sulfide has a *negative* temperature coefficient of electrical resistivity, in contrast to metals [1]. He made the remarkable discovery that silver sulfide behaved as an insulator at room temperature but exhibited high electrical conductivity at elevated temperatures. However, the two fields, namely electrochemistry and solid state science, came together in the work of Edmond Becquerel, in 1839, on the electrochemical photovoltaic effect: he showed that if one of the two identical electrodes immersed in a common electrolyte is exposed to a suitable illumination, a voltage change can be observed [2]. This may be taken as the *birth* of solid state electrochemistry, also termed previously as electrochemical physics [3]. A formal definition of this field has been proposed as follows [4, 5]:

> Electrochemical physics is the vast area of modern research which deals with the electrochemical properties of materials in relation to their solid state characteristics. It thus explores the electrochemical charge transfer events in and on solids in terms of parameters and considerations defining their behavior in the solid state.

Early examples of seminal work in this field are the investigations of Gurney on ions in solutions [6] and in crystals [7], as well as his theory of charge transfers across interfaces [8]. He had benefitted much from the guidance and help of a leading solid state physicist, namely Mott, who himself made very fundamental contributions to the theories of the double layer [9, 10] and the anodic oxide growth on metals [11, 12]. Contributions of Wagner to solid state electrochemistry are of epic proportions and still constitute the anchor of most textbooks on the subject [13].

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The landscape of solid state electrochemistry is very vast and a synoptic glimpse of the richness of problems involved is given in Table 1 [4, 5], which is only illustrative and by no means exhaustive.

The fascinating field of solid state electrochemistry is immensely enriched by the challenging problems one also tackles in its applications to many societal issues, especially those involving energy, environment, advanced materials and biotechnology [14–16]. A few examples of these applications that immediately come to mind are: batteries; fuel cells; sensors; supercapacitors; conducting polymers; photoelectrochemistry; clays and zeolites; electrocatalysis; sol-gel materials in electrochemistry; surface treatments of metals; electrochemistry in power engineering, electronics, geology, civil engineering (e.g., stability of soils), environmental engineering (e.g., solid wastes, electrochemical remediation) and, of course, electrochemistry in chemical and metallurgical engineering. Also to be included are the electrochemical properties of, and processes in, biological materials. Many new and unexpected problems are emerging every day and perhaps the reader will indulge the present author by allowing him to illustrate two such applications from his own recent work: (1) electrochemical dewatering of colloidal suspensions and "fines" produced by industries in the areas of mining and metallurgy, paints, textiles, pharmaceuticals, food and agriculture, etc. [17]; (2) electrochemical treatment of cancerous tumours in which the successful experimental results obtained in China on thousands of patients have been interpreted by the present author in terms of electrochemical concepts [18, 19].

In conclusion, interaction of solid state materials science with electrochemistry has created a large and challenging area of research variously called solid state electrochemistry or electrochemical physics (cf. physical chemistry or chemical physics?). This may be encapsulated as:

$$\left.\begin{array}{c}\text{Electrochemistry}\\+\\\text{Solid state science}\end{array}\right\}\rightarrow\begin{array}{c}\text{Solid state electrochemistry}\\\text{or}\\\text{Electrochemical physics}\end{array}$$

Table 1 Some illustrative areas of fundamental research in solid state electrochemistry/electrochemical physics

Electrochemistry of semiconductors
Electrochemistry of insulators (e.g., anthracene)
Anodic oxide growth on metals and semiconductors
Reactions on demetallized surfaces and coated electrodes
Electrocatalysis by metals, alloys and intermetallics
Chemical physics of interfaces; double layers and their electrochemical thermodynamics and statistical mechanics
Role of crystal imperfections in metal deposition and dissolution reactions
Solid electrolytes: ice, polymers, ceramics, superionic conductors
Energy levels in solids and electrolytes
Electrobiophysics
Quantum mechanical treatments of charge transfers
Photoelectrochemistry
Ionic transport through membranes
Fractals on electrodic surfaces
Solitons in polymeric batteries
Metal-plasma interfaces
Metal-dielectric interfaces

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