

## Recent Progress in Electrochemical Surface Science with Atomic and Molecular Levels

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Until the mid 1980's, there had been only few *in situ* methods available for structural determination of an electrode surface in solution at atomic and monolayer levels. Nowadays, many powerful *in situ* techniques, such as electrochemical scanning tunneling microscopy (EC-STM), infrared reflection absorption spectroscopy (IRAS), surface-enhanced Raman scattering (SERS), and surface-enhanced infrared reflection absorption spectroscopy (SEIRAS), second harmonic generation (SHG), sum frequency generation (SFG), and surface X-ray scattering (SXSS) have been widely employed to characterize the electrode surfaces under potential control with atomic and/or molecular resolution. The object of this review is to highlight some of the progress on *in situ* methods at solid-liquid interface with atomic and molecular levels. Several selected topics are focused on, specifically adsorbed anions on metal surface, electrocatalysis of the carbon oxide oxidation and dioxygen reduction, and direct observation of single crystal electrode surfaces.

**Key Words :** Solid-Liquid Interface, Single Crystal Electrode, Adsorption, Structure, Adlayer, Electrocatalysis, SHG, SFG, SXSS, SEIRAS, STM

### 1 General Introduction

Kingo ITAYA & Soichiro YOSHIMOTO

Electrochemistry is important for industries concerned with products and processes such as batteries, fuel cells, electroplating, corrosion inhibition, electro-organic synthesis, and sensor devices.<sup>1</sup> Because electrode reactions take place at solid-liquid interface where the electrode is in contact with a solution, electrochemical interface plays an important role in controlling the electron transfer reaction. Understanding the nature of solid-liquid interface in detail not only leads to the elucidation of the electrode reaction mechanism but also provides information useful for designing new interfaces.

As a fundamental basis for all electrochemical studies, electrode-electrolyte interfaces must be prepared reproducibly, and methods must be established to observe these interfaces accurately. It is still difficult to elucidate electrochemical reactions on the atomic scale using polycrystalline electrodes. Well-defined single crystal surfaces must be exposed to solution to understand surface

structure-reactivity relationships on the atomic scale. Efforts have succeeded to produce extremely well-defined, atomically-flat surfaces of various electrodes made of noble metals, base metals, and semiconductors without either oxidation or contamination in solution.<sup>2,3</sup>

It was first realized in 1960 in the field of electrochemical surface science that the adsorption-desorption reaction of hydrogen on Pt single crystal electrodes is strongly dependent on their crystallographic orientations; this demonstrated the importance of the nature of metal surface at the atomic level.<sup>4,5</sup> Clavilier was the first to develop a simple and important experimental method, the so-called *flame annealing and quenching method*,<sup>6</sup> to expose well-defined electrode surfaces in aqueous electrolyte solutions without the use of ultrahigh vacuum (UHV) techniques. Nowadays, this technique has been extended by Hamelin for Au<sup>7,8</sup> by Motoo and Furuya for Ir,<sup>9</sup> and by Itaya's group for Rh and Pd.<sup>10</sup>

Meanwhile, since the late 1980's, *in situ* analytical methods were developed all over the world. In the early stage, various experimental techniques, such as infrared absorption spectroscopy (IRAS),<sup>11-13</sup> ultra-violet (UV)-vis-

# Recent Progress In Surface Science

**Mark Steyvers**



## **Recent Progress In Surface Science:**

**Recent Progress in Surface Science**, 1964 *Recent Progress in Surface Science* J. F. Danielli, K. G. A. Pankhurst, A. C. Riddiford, 2013-10-22 *Recent Progress in Surface Science Volume 1* reviews significant advances made in surface science during the period 1956-1961 as well as problems that are still unsolved. Topics covered range from surface viscosity and electrode processes to corrosion of metals, surface active substances and foams and free liquid films. The electrical double layer and electrokinetic phenomena are also examined along with facilitated diffusion and the chemistry of the semiconductor surface. Comprised of 11 chapters, this volume first deals with surface viscosity and general principles and applications of surface rheology as well as the viscosity of various types of monolayers. The reader is then introduced to foams and free liquid films with emphasis on the theory of foaming, the electrical double layer and electrokinetic phenomena and electrode processes. Subsequent chapters explore the corrosion of metals, surface active substances, surface chemistry of compound and organic semiconductors and the mechanism of facilitated diffusion. The book also considers the morphology and dynamic aspects of cell contacts before concluding with an analysis of the formation and properties of bimolecular lipid membranes. This book will be of interest to chemists and physicists.

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J. F. Danielli, A. C. Riddiford, M. D. Rosenberg, 2013-10-22 *Recent Progress in Surface Science Volume 3* covers topics on the structure and mechanisms of the cell membranes. The book discusses the incorporation of chemisorbed species, the recent developments in the study of epitaxy and the diffusion or hydride component of overpotential at cathodes of the platinum metals. The text also describes the mechanism of hydrogen exchange in proteins, the nuclear magnetic resonance studies of lipids, lipoproteins and cell membranes and the monolayers of synthetic phospholipids. The formation, electrical properties, transport and excitability characteristics of black lipid films, the structure of biological membranes, the lamellar versus the globoid concept and some aspects of the role of lipids in lipid-protein interactions and cell membrane structure and function are also considered. The book further tackles ordered water and the ultrastructure of the cellular plasma membrane. Chemists, biophysicists, biochemical pharmacologists and biochemists will find the book useful.

**Recent Progress in Surface Science** J. F. Danielli, K. G. A. Pankhurst, A. C. Riddiford, 2013-10-22 *Recent Progress in Surface Science Volume 2* is a 10 chapter text that covers the significant advances in some aspects of surface science including catalysis, genetic control of cell surface and cell membrane. The opening chapter deals with the major factors affecting adsorption at the gas-solid

interface The subsequent chapters explore the advances in understanding of heterogeneous catalysis in terms of fundamental surface processes as well as the concept of dynamic contact angles These topics are followed by discussions on emulsions flotation and the extraordinary complexity of cell surface structures and their chemical components Other chapters consider the experimental studies on the physiology of pinocytosis and the principles of plastron respiration The final chapters are devoted to the isolation characterization and electronmicroscopic studies of cell membrane This book is of value to surface scientists cell biologists and researchers in the allied fields

**Recent Progress in Surface Science**, 1970 **Surface Science: Recent Progress and Perspectives** Gert Ehrlich, 1982 **Surface Science** T.S. Jayadevaish, R. Vanselow, Chemical Rubber Company, 1974 *Applied Surface Science* Gurrappa Injeti, 2019-10-02 This book covers the state of the art and recent advances in the field of surface science of a variety of materials for different applications and provides an in depth understanding of mechanisms involved in achieving the desired surface properties The book is extremely useful to materials scientists system design engineers maintenance engineers manufacturing experts and executives industrialists mechanical engineers chemical engineers aeronautical engineers academic researchers and undergraduate and postgraduate students [Serial Holdings in the Pennsylvania State University Libraries](#) Pennsylvania State University. Libraries, 1975 *Serials Holdings in the Linda Hall Library* Linda Hall Library, 1986 [Recent Advances in Nano-Tailored Multi-Functional Cementitious Composites](#) Mustafa Şahmaran, Faiz Shaikh, Gürkan Yıldırım, 2022-03-08 Over the past few years concrete technology has advanced quite dramatically thanks to the use of a great variety of additives and admixtures which have paved the way for the effective development of new generation concrete mixtures Among these additives and admixtures nanomaterials used in construction materials such as paste mortar and concrete mixtures have become very popular recently Much of the previous attention in regard to the utilization of nanomaterials in construction materials was specifically devoted to the characterization of their fresh state hydration microstructure pore structure mechanical transport and durability properties However research into the tailoring of multi functional properties of construction materials especially cementitious with the use of nanomaterials is still in its infancy *Recent Advances in Nano Tailored Multi Functional Cementitious Composites* aims to capture recent major scientific advances and the current state of the art in multi functional cementitious composites developed with nanomaterials The book will provide researchers engineers and other stakeholders with an insight into future directions of multi functional capabilities of cementitious composites Chapters focus on the large scale development characterization and application of multi functional cementitious composites addressing the following topics nano modified concrete strain hardening cementitious composites self sensing concrete self healing and bacteria based concrete self cleaning concrete self consolidating concrete material construction technology for 3D printing thermal insulation capability green concretes including geopolymer concrete nanoscale characterization methods low CO<sub>2</sub> reactive magnesia cements and future developments and challenges of nano tailored

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