Chapter 15
Morphology and Functionalization of Metal Foils and Other Surfaces for Electrochemical Applications

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ABSTRACT

Electrochemical applications had their first major impact in the late 20th century with the development of improved energy storage and conversion systems such as lithium-ion batteries, organic-inorganic dye-sensitized solar cells, and even e-ink displays. Depending on the requirements, the electrodes can be made of different materials, such as metal or alloy sheets, foils, bars or conductive ceramics, conductive polymers, etc. In this chapter, methods for surface functionalization and characterization of metallic and non-metallic surfaces used as electrode substrates are presented. The focus is on the use of metal foils in lithium-ion batteries and especially in the novel architecture of optoelectronic devices – from electrochromic and photovoltaic devices to biosensors.

INTRODUCTION AND BACKGROUND

Metal foil technology flourished in the 20th century, especially in the automotive and aeronautic industries (Barroqueiro, Andrade-Campos, Valente, & Neto, 2019) (Orsato & Wells, 2007). The use of metal foils had its particularity in the 1950s, when it was widely used in both industries, as well as in the packaging industry, where the use of aluminum was widespread (Lamberti & Escher, 2007). This packaging

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technology was soon rendered obsolete by the introduction of polymer materials, which eventually found their way also into the automotive and aeronautic industries (Muhammad, Rahman, Baini, & Bin Bakri, 2021). Nevertheless, metal foils remained indispensable in certain sectors, and the rise of advanced electrochemical applications opened up new uses for the old technology. A great example of this represents widely used lithium-ion batteries design, which commonly use aluminum and copper foil as a current collector as well as to improve mechanical characteristics of device (Goodenough, 2018) along with photo/electrocatalysis devices that can be used for either chemical processing (Marinko et al., 2021) or energy storage (Dinh et al., 2019). There was particular interest in the development of semiconductors that could be used for advanced electronic systems (microprocessors) that could be further miniaturized and used in various devices (Covington, 1994). With the advent of miniaturization, the demand for energy storage devices increased as the older lead-lead oxide batteries simply could not keep up with the demand for energy. In addition, the space race between the United States and USSR began in the early 1950s, requiring the development of energy conversion systems that could operate reliably under extreme conditions, even in the space vacuum (Prince, 1955). These energy conversion systems focused on the development of photovoltaics and fuel cells, which initially had relatively limited applications, but soon attracted a great deal of interest in the 1970s and 1980s, when the world economy was beset by various energy crises (e.g., 1973 oil crisis, 1979 Three Mile Island incident, 1986 Chernobyl accident) and demanded new solutions that would make the world energy redundant (Chowdhury, Sumita, Islam, & Bedja, 2014). Electrochemical applications had their first major impact in the late 20th century with the development of improved energy storage and conversion systems such as lithium-ion batteries, organic-inorganic dye-sensitized solar cells, and even display screens (e.g., light-emitting diodes and e-ink displays) (Whittingham, 1974) (O'Regan & Grätzel, 1991) (Fischer, von Brüning, & Labhart, 1976) (Maruska & Stevenson, 1974). With the increasing development of computing and entertainment technologies and the widespread use of portable devices such as smartphones and tablets, energy storage systems and various optoelectronic devices are of great interest, not only for scientific research, but also for industry and consumers. Due to the increased interest of entertainment industry and information sector, any improvement in this field is greatly encouraged both from scientific and financial aspect.

Most electrochemical devices have a similar structure: they consist of (i) at least two highly conductive surfaces that act as electrodes, (ii) an electrolyte, which can be liquid, solid or quasi-solid, and (iii) an insulating container that prevents the device from short-circuiting and ensures that the contents of the device are not released into the environment. Depending on the requirements, the electrodes may be made of various materials, such as metal or alloy sheets, foils, bars or form conductive ceramics and conductive polymers, with the substrate material having significant influence on the further selection of the coating process. While metal foils are considered durable, flexible and temperature resistant (aluminum foil is an excellent example), some materials have their own advantages and disadvantages. One such class of materials are optically transparent materials, which are commonly used in optoelectronic applications such as solar cells and e-ink displays. These materials can be made from conductive polymers, ceramic-coated glass, or even thin film metal deposits on glass or plastic substrates. While conductive polymers and coated polymer substrates have interesting mechanical properties such as flexibility and stretchability, they are less suitable for high temperature refinement (above 100 °C) and can become brittle at lower temperatures. Ceramic substrates, on the other hand, are very temperature resistant but have a rigid structure. As there is an increased requirement in preparation of new ways to produce large quantities of low-cost materials, that can be used in high technology sectors such as optoelectronics, biomedical

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