Electrochemical Manufacturing in the 21st Century

by Dennie T. Mah

To quote Sir James Dyson, of the bagless vacuum cleaner fame, "Manufacturing is more than just putting parts together. It involves coming up with ideas, testing principles and perfecting the engineering, as well as final assembly." The making of goods and wares on a large scale requires the integration of science and technology, along with engineering discipline, manufacturing knowhow, and business and marketing acumen to yield quality products at a reasonable price. And so it is with electrochemical manufacturing. James McIntyre[1] has authored an excellent review of the first 100 years of industrial electrochemistry if you have an interest in this topic. John O'M. Bockris[2] wrote that electrochemical manufacturing spans a vast array of applications – production and purification of metals such as aluminum, copper, zinc, or sodium; inorganic electrochemical process such as chlorine, sodium hydroxide, fluorine, hydrogen, and oxygen; organic electrochemical processes such as adiponitrile; electroplating and electrocoating such as decorative or protective coatings on metal or plastic; electromachining and electroforming to shape metallic parts; and corrosion prevention to avoid destructive dissolution of metals. As with any manufacturing process, troubleshooting and quality control are keys to maintaining a viable product. Electrochemical techniques such as offline and online electroanalytical measurements and electrochemical impedance spectroscopy have been developed to eliminate product defects.

Having worked in the chemical industry for 40 years, I have come to appreciate the wisdom of electrochemical pioneers like Robert Burns MacMullin[3,4] who tackled the subject, "The Problem of Scale-Up in Electrolytic Processes." Dan E. Danly[5] published an all-encompassing evaluation of electrochemical plant design and economics. A plethora of publications have evolved to guide both the novice and veteran practitioners of electrochemical manufacturing. Yet, a basic hurdle that I have encountered in industry is the lack of the decision maker's awareness of electrochemical manufacturing. We at ECS should not take for granted that everyone is familiar with electrochemical science and technology. Ask chemical engineers how to separate a mixture and they will first respond, "Why distillation of course!" Today, distillation is very well understood; but, it is an energy intensive unit operation with high operating costs. Unfortunately, many traditional manufacturing options acquire precedence based on past successes while electrochemical technology is overlooked.

Upon reflection, I believe electrochemical manufacturing progress is stymied by the lack of practical knowledge. This is partly due to the confidential nature of manufacturing. Inadvertent and costly manufacturing mistakes are made every day through the "reinventing of the wheel" syndrome. If only there were more dissemination of case histories and "tips, tricks, and traps" of electrochemical manufacturing, this sector could avoid the "discovery, practice, and loss" cycle. Most of my industrial career was spent in chemical engineering consulting and it never ceased to amaze me how I could walk into a manufacturing location and find that a new or current operation had lost its way, resulting in unacceptable product defects.

Manufacturing people don't need to know all the underlining principles of the science and technology. But, they do need to know what is important to successfully transform raw materials into marketable products. The challenge for scientist and engineers is to reduce both established and novel electrochemical technologies to practical, everyday applications. Today, as manufacturing protocols and product specifications become ever more complex, electrochemical manufacturing success depends on a multi-disciplinary, multi-team, collaborative approach. The ECS IE&EE Division has recognized this fact with its New Electrochemical Technology (NET) Award presented every odd year.[6]

Looking toward the future, electrochemical manufacturing faces the issue of readily available, low-price electricity if it is to grow and prosper. Where will electricity come from? How will it be distributed? Can it be stored? What would be the environmental impact? And, in my opinion, how efficiently can the electricity be utilized? Whether you consume or produce electricity, I found in general that you can expect to obtain a voltage efficiency of say 50%; the rest of the energy being lost as heat. Thus, voltage efficiency is a major crux in the pathway to exploiting electrochemical manufacturing.

In this issue of *Interface,* three articles take a look at various facets of electrochemical manufacturing, ranging from an overview of traditional and emergent avenues of electrochemical manufacturing in the chemical industry, to electrochemical surface finishing and impedance based characterization of raw materials. In the case of electrochemical surface finishing, E. J. Taylor and M. Inman reveal to us that not only is the process more robust; but, the manufacturing cost is lower. D. Riemer and M. E. Orazem demonstrate how electrochemical impedance spectroscopy (EIS) can measure the state of the oxide film on raw materials, which is a critical parameter in electrochemical through-mask etching of stainless steel parts. Finally, G. Botte revisits industrial electrochemical processes used to synthesize both organic and inorganic chemicals and introduces new opportunities in electrochemical manufacturing. These authors welcome your interest in their work and hope that their viewpoints stimulate future dialogue in the exploitation of electrochemical manufacturing.

About the Author

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