Interfacial phenomena in lithium batteries and beyond

Lithium-ion batteries (LIBs), possessing a far higher gravimetric and volumetric energy-density amongst commercially viable battery systems, have certainly enabled the exceptional expansion of portable electronics, such as mobile phones, where space and weight limitations are paramount, in turn enabling the wireless communicating society in which we live. Recently, the use of LIBs has also risen in the automotive industry enabling the rapidly increasing production and proliferation of electric vehicles, which are expected to lead the overall mass market in the near future and coming more and more into play for stationary storage.

A fundamental role in the development of LIBs has been played by the seminal work of Prof. Emanuel Peled "The Electrochemical Behavior of Alkali and Alkaline Earth Metals in Nonaqueous Battery Systems—The Solid Electrolyte Interphase Model" published in 1979 [1]. This ground-breaking manuscript describing the solid electrolyte interphase (SEI) constitutes a paradigm change in the understanding of lithium batteries and has thus enabled the development of safer, durable, higher-power and lower-cost batteries. Its wide use is demonstrated by more than 2000 citations in SCOPUS. The Google Scholar search for the term "SEI lithium ion battery", yields 1,080,000 results, while a search for the "lithium ion battery electrochemistry" yields 1,090,000 results. That is, in almost 100% of the articles on lithium batteries, the SEI model is used to analyze the experimental results.

Prior to the publication of the SEI model (1979), researchers in this field used the Butler-Volmer equation, in which direct electron transfer from the electrode to lithium cations in the solution is assumed. The SEI model showed that this is the wrong approach; the Butler-Volmer equation is not applicable and lithium batteries cannot function at all without a proper SEI that prevents electron transport to the solution. Thus the electrolyte has to contain a proper SEI precursor. The SEI determines the safety, cycle life, power and shelf life of the lithium batteries. The SEI model provides new equations for the deposition-dissolution kinetics of lithium during battery charge and discharge processes (which are different from those for aqueous batteries like zinc batteries), for lithium anode corrosion, for the resistivity of the SEI, for the growth rate of the SEI, for the exchange current density, for the "Tafel" slope and its dependence on SEI thickness [1–5]. It explains the reasons and the mechanisms of lithium dendrites formation on charge that may lead to internal shorts, thus to battery thermal runaway situations, especially critical for large EVs batteries. It explains the difference in behavior of anodes whose SEI is a cations or anions conductor.

With regards to electromobility and besides LIBs and alkali metal batteries [6–8], Prof. Peled has also contributed to the development of fuel cells (FCs). In particular, he developed a high performance and very-low-cost nanoporous proton-conducting membrane enabling the realization of a direct methanol and for the first time a direct ethylene glycol fuel cells and a hydrogen tribromide fuel cell [9,10].

For his achievements in the field of electrochemical power sources Prof. Peled received many awards, including the Electrochemical Society Battery Division Research Award, the Landau Research Award, the Israel Chemical Society Outstanding Scientist Award, the Award of Commander of MAFAT (Israel MOD) for Creative Thinking and the 2019 Samson - Prime Minister's Prize for Innovation in Alternative Fuels and Smart Mobility. In 2022 Prof. Peled was awarded by the Gold Medal of Excellence 2022 of the International Battery Association (IBA). This recognition is devoted to acknowledge exceptional life-long contributions to electrochemical energy conversion and storage research and technological development. He was also elected Fellow of the Electrochemical Society and of the International Society of Electrochemistry.

Over the years Prof. Peled established and built a large and extensive research group of young male and female students. Until now he supervised over 40 PhD students. All students were nurtured and grew into productive scientists due to his teaching and scientific mentoring. They became mature and sought-after experts in different research groups and industrial companies.

Prof. Peled also demonstrated ability in transforming science to real application co-founding four energy related start-up companies based on technology developed in his laboratory dealing with battery meters (Chemtronics), redox flow cells (Enstorage), 3D batteries (Honeycomb) and silicon nanowire anodes (SiLiB).

Finally, Emanuel is not only a teacher, but a friend, philosopher, and guide – all melded into one person.

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