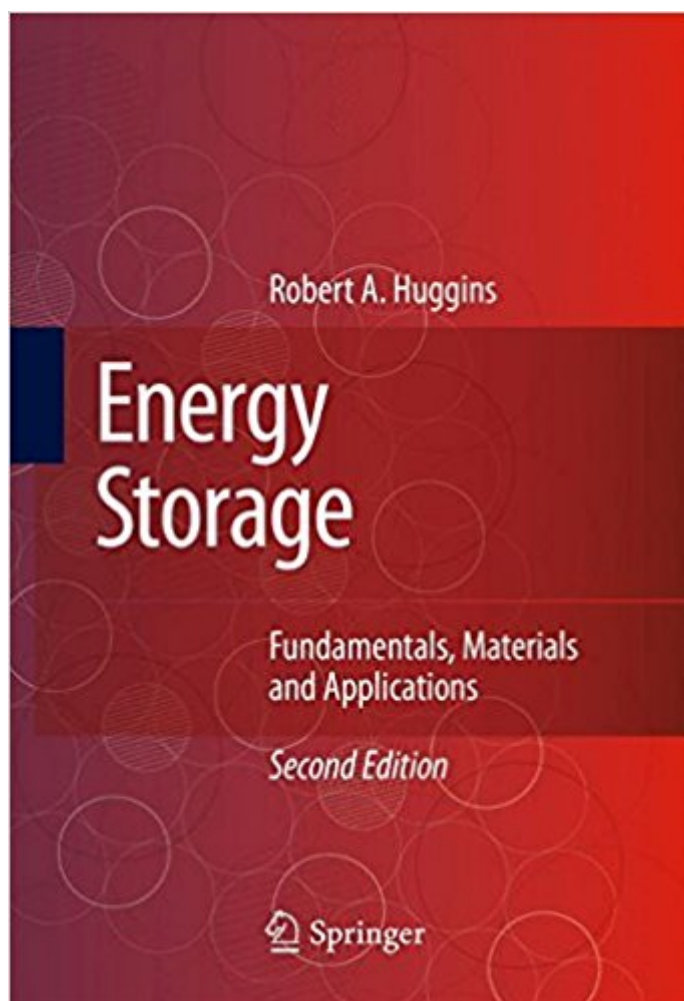


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# Energy Storage: Fundamentals, Materials And Applications



## Synopsis

Energy Storage explains the underlying scientific and engineering fundamentals of all major energy storage methods. These include the storage of energy as heat, in phase transitions and reversible chemical reactions, and in organic fuels and hydrogen, as well as in mechanical, electrostatic and magnetic systems. Updated coverage of electrochemical storage systems considers exciting developments in materials and methods for applications such as rapid short-term storage in hybrid and intermittent energy generation systems, and battery optimization for increasingly prevalent EV and stop-start automotive technologies. This nuanced coverage of cutting-edge advances is unique in that it does not require prior knowledge of electrochemistry. Traditional and emerging battery systems are explained, including lithium, flow and liquid batteries. Energy Storage provides a comprehensive overview of the concepts, principles and practice of energy storage that is useful to both students and professionals.

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Explains the fundamentals of all major energy storage methods, from thermal and mechanical to electrochemical and magnetic Clarifies which methods are optimal for important current applications, including electric vehicles, off-grid power supply, and demand response for variable energy resources such as wind and solar New and updated material focuses on cutting-edge advances including liquid batteries, sodium/sulfur cells, emerging electrochemical materials, natural gas applications and hybrid system strategies This book explains the underlying scientific and

engineering fundamentals of all major energy storage methods. These include the storage of energy as heat, in phase transitions and reversible chemical reactions, and in organic fuels and hydrogen, as well as in mechanical, electrostatic and magnetic systems. Updated coverage of electrochemical storage systems considers exciting developments in materials and methods for applications such as rapid short-term storage in hybrid and intermittent energy generation systems, and battery optimization for increasingly prevalent EV and stop-start automotive technologies. This nuanced coverage of cutting-edge advances is unique in that it does not require prior knowledge of electrochemistry. Traditional and emerging battery systems are explained, including lithium, flow and liquid batteries. Energy Storage provides a comprehensive overview of the concepts, principles and practice of energy storage that is useful to both students and professionals.Â

Professor Huggins obtained his B.A. in Physics from Amherst College and his M.S. and Sc.D. in Metallurgy from the Massachusetts Institute of Technology.Â Â After serving as an Instructor at MIT, he joined the Stanford faculty, where he initiated the Department of Materials Science and founded Stanford's Center for Materials Research. His career has included a National Science Foundation Fellowship and guest lectureship at the Max-Planck-Institute, as well as terms as Director of Materials Sciences at ARPA, Chief Scientist of the Center for Solar Energy and Hydrogen Research in Ulm, Germany, and Chairman of the Solid State Sciences Committee. He was a member of the Committees on Advanced Energy Storage Systems and Battery Materials Technology of the US National Academy of Sciences and the first President of the International Society for Solid State Ionics. He was also one of the Founders, and later twice a Counselor, of the Materials Research Society. He is Honorary Professor at the University of Ulm and the University of Kiel. Dr. Huggins is recipient of many awards including the American Society for Engineering Education's Vincent Bendix Award, the Research Award of the Electrochemical Society's Battery Division, and the Research Award of the International Battery Association. His research activities have included studies of imperfections in crystals, solid-state reaction kinetics, ferromagnetism, mechanical behavior of solids, crystal growth, and a wide variety of topics in physical metallurgy, ceramics, solid state chemistry and electrochemistry. Topics of particular recent interest have been hydrogen transport and hydride formation in metals, alloys and intermetallic compounds, and especially, various aspects of materials and phenomena related to advanced batteries. He is author or co-author of over 400 publications, including 150 articles or chapters in books and conference proceedings, as well as 13 patents.Â He is Editor of several books, including of the 23-volume book series Annual Review of Materials Science. He has also been an Editor of Solid State Ionics journal,

Associate Editor of the Materials Research Bulletin, on the Advisory Review Board of the Journal of Materials Research, and on the Editorial Boards of Progress in Solid State Chemistry, the Journal of Power Sources, and Ionics, as well as the European Journal of Solid State and Inorganic Chemistry. In addition to his many research publications, he is the author of two recent books published by Springer, *Advanced Batteries: Materials Science Aspects and Energy Storage*.

By 16 in 1945: This is an extended update of the excellent book, *Energy Storage*, that was published in 2010. As in the earlier version, it provides an excellent overview of the various methods that can be used for the storage of energy. It is an outstanding textbook, for the various topics are discussed in a manner that teaches the important principles involved, and from the point of view of materials science, not just electrochemistry. It begins with a long preface that describes various types of energy sources and fuels, as well as the development of fracking. The tendency to move away from nuclear energy sources as the result of the major disasters at Chernobyl in the Ukraine and Fukushima in Japan, and the growth of the use of alternate sources of energy, such as solar and wind are also discussed. There is a discussion of the storage of heat by the use of reversible chemical reactions and phase-change materials, as well as reversible chemical reactions, and in a variety of organic fuels. Mechanical energy can be stored as either potential energy or kinetic energy by several techniques, including pumped water and flywheels. Electrical energy storage can involve the use of capacitive, magnetic, or superconductive systems. There is also a thorough discussion of the various methods for the production and storage of hydrogen. As before, more than half of the total pages are dedicated to the storage of energy in electrochemical systems, and that is where this book stands out from all the others that deal with energy storage. Rather than merely describing the different types of batteries, it teaches the factors that determine the voltages and capacities of electrochemical systems and devices, as well as their kinetic properties. A wide range of related topics are discussed, including heart pacemaker power sources, the common non-rechargeable alkaline cells, metal hydride cells, lithium-ion batteries, and the flow batteries that can play an important role in connecting intermittent sources, such as wind and solar, to the large-scale electrical power grid. The discussion of the common lead-acid battery is very different from what is available in other books. Based upon materials science principles, it explains how these water-based electrochemical cells can have voltages well beyond the theoretical stability range of water. New content in this edition includes an extended chapter with a thorough discussion of various aspects of potentials in electrochemical systems, and the various types of reference electrode systems. There is also considerable additional material on a number of topics, including

primary, non-rechargeable, systems, and various aspects of zinc electrode behavior. The characteristics of materials that are solid electrolytes, in which charge is carried primarily by ionic species, and mixed ionic-electronic conductors, which have both ionic and electronic defects in their structures, are explained. The long chapter on "Energy Storage for Medium-to-Large Scale Applications" is especially interesting. It includes discussions of a number of current topics that are not found in typical books on electrochemistry. One of these is materials with unusual crystal structures. This includes electrode materials with ionic-sized tunnels, and another family with an open framework type of structure. The most interesting of the latter are in the "Prussian Blue" family. These inexpensive materials are stable in aqueous electrolytes, and have been shown to operate at very high rates for many cycles. A new class of composite anode materials that are compatible with the Prussian Blue materials is also discussed. These have a hybrid microstructure that includes a doping reaction at a constant potential along with a capacitive reaction. They also have a lifetime of many cycles. Additional topics in this chapter include batteries with liquid electrodes, flow batteries, and new all-liquid systems. The last chapter, "A Look at the Future", discusses a number of interesting current research directions.

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