# Advanced Electrochemical Nanomaterials: Interplay of Structure and Properties in Transition Metal Compounds

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**Abstract**

Transition metal compounds (e.g. $MX_y$ where M=V, Fe, W, Mn, etc.; X=O, B, S, etc.) have important applications in batteries, supercapacitors, fuel cells, electrochromic devices, photovoltaics, electrolyzers, and sensors. By designing transition metal compounds as nanomaterials, materials with distinct structures and properties that differ compared to either individual molecules or bulk forms can be obtained. The design of nanomaterials with improved properties involves understanding and controlling surface structure, defects, interparticle interactions, particle size, and pore size and distribution. The internal and surface structure of nanoscale vanadium diboride ($VB_2$) is significantly different than in macroscale forms, and nano-$VB_2$ shows enhanced multi-electron electrochemical charge storage properties. In nanomaterials, unique structures such as defects and amorphous phases can be stabilized. Cation defects can be controlled in magnetic iron oxide ($FeO_x$) nanomaterials and result in improved electrochemical properties. Connections between nanoparticles also play an important role in properties. Significantly higher electronic conductivities and long-range proton transport are obtained by using manganese oxide ($MnO_x$) nanoarchitectures with interconnections between particles rather than using particulate films. The unique and controllable structures and properties of nanomaterials provide a pathway to develop improved electrochemical materials. Current research directions include two-dimensional materials for energy storage and conversion, designed surfaces and interfaces for rapid charge transport, and spectroscopic characterization of surface structure and reactivity.

**Biosketch**

Dr. Rhodes' research involves studying the structure and properties of electrochemical materials, and he has contributed to the research and development of advanced materials for batteries, supercapacitors, fuel cells, electrosynthesis of hydrogen peroxide, and solar hydrogen production. Dr. Rhodes received a B.A. in Chemistry in 1992 from Texas A&M University and received his Ph.D. in Physical Chemistry in 2001 from the University of Oklahoma. Subsequent to his doctoral work, Dr. Rhodes held an Office of Naval Research–MURI postdoctoral appointment at UCLA in the Department of Materials Science and Engineering and a joint appointment as a contractor at the U. S. Naval Research Laboratory in the Surface Chemistry Branch. Following his postdoc, Dr. Rhodes spent nine years in a private company, Lynntech, Inc., where he developed and commercialized advanced technologies. Dr. Rhodes accomplishments include numerous published articles in peer-reviewed journals, an issued patent, and numerous presentations at international meetings. Dr. Rhodes has served as Principal Investigator (PI) on grants and contracts from the National Science Foundation, Department of Energy, Department of Defense, and National Aeronautics and Space Administration. In addition to his research experience, Dr. Rhodes has experience in technology development and commercialization, and his research has resulted in two products that were purchased by private companies.