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FUTURE DIRECTIONS IN MOLTEN SALT RESEARCH AS IT RELATES TO ENERGY STORAGE

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Future Directions in Molten Salt Research as it Relates to Energy Storage

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The future directions for molten salt research relevant to eletrochemical energy storage may be discussed in several categories, which are found to be in rather different states of maturity.

The thermodynamics of the relevant molten salt electrolyte systems and the various electrode systems under serious consideration are in the best state of any of the topics discussed here. Many phase diagrams of interest (and potential interest) for molten-salt electrolytes have been measured and calculated. In general, the calculated diagrams agree very well with the measurements, giving confidence that computations, together with only a few measurements can yield high-quality phase diagrams for multi-component alkali-halide systems. The phase diagrams for solid electrodes are generally more complicated and less predictable, but many of them have been measured with good accuracy. Also, the activities of the relevant components have been measured, yielding the essential thermodynamic information. This general topic of electrode and electrolyte thermodynamics is in an adequate state of development. For the future, it is to be expected that more sophisticated thermodynamic models and computational methods will provide for more powerful tools to be used in the estimation of the properties of more complex systems.

Techniques for the study of the molecular structure and speciation in molten-salt electrochemical systems are being developed, but are still in their infancy. This field suffers from a low level of effort, combined with the inherent difficulty of performing high-precision experiments <u>in situ</u> at elevated temperatures and (usually) in controlled atmospheres. Raman spectroscopy and UV-visible absorption spectroscopy have shown success for the study of the bulk electrolyte phase; extension of Raman to electrode surfaces is an important goal. Perhaps infrared spectroscopy for electrode surfaces can also be developed. Other techniques such as photothermal deflection spectroscopy are candidates. Ultimately, scanning-tunneling microscopy may be feasible for studying the structure of electrode surfaces in-situ, and on an atomic scale.

The study of the kinetics and mechanisms of electrode reactions has been following the lead of work in ambient-temperature systems. Steady-state techniques have been in use for some time. Transient techniques are finding wider use. Voltage-sweep methods are most common, followed by potential-step and current-step methods. Recent improvements in pulse and double-pulse methods have been made, improving the accuracy available for fast reactions.

As more is learned about the details of operation of the various electrodes that comprise the systems of interest, it becomes more important to

have available sophisticated mathematical models for electrodes and complete cells. These models, appropriately implemented on computers, can provide for new levels of understanding with regard to the complex interactions among the many variables in practical porous-electrode systems. They can also be used as design tools, helping to meet specific performance goals, while reducing the need for large numbers of experiments. The recent advances in computer speed, memory size, and cost reduction provide a major opportunity to advance the contributions that can be made by modeling. The future is certain to provide more detailed and powerful models of electrochemical cells, including models with the capability of providing information about the behavior of rechargeable cells undergoing many charge-discharge cycles.

New materials can be expected to continue to set the pace for the development of advanced electrochemical energy conversion systems. They will play a central role in setting the limits of the performance and life capabilities of new and existing systems. New materials and new processes can also be expected to play key roles in reducing the cost of new systems in order to compete in the marketplace. Both active materials and the (inactive) materials of construction for cells can either prevent or enable the success of any electrochemical system. Too often, adequate attention to materials problems has been left until last in the R&D cycle. In the future, an earlier appreciation of materials development is expected. More sophisticated methods of materials synthesis and quality control will be necessary. It is likely that electrochemical methods for the preparation of special high-performance materials will be used to a greater extent in the near future.

There is now a window of opportunity for new, high-performance batteries to be developed and enter various markets -- before other advanced systems are developed. If this opportunity can be used successfully, then a strong competitive position will be established for molten-salt batteries. If not, then the development of a marketable battery will be much more difficult, because the new battery will be called upon to displace a competing system which is already established. Based on current research results, it appears feasible to develop a molten-salt battery capable of 200 W/kg, 200 W-h/kg, 500+ deep cycles, and at least 2 years operating life, with a cost acceptable for specialty applications. These cells are very robust, can resist many thermal cycles, have a good packing density, and require only simple temperature control.

The aggressive development of a high-performance molten-salt battery should be a high-priority goal, if we are to meet our battery needs. If the U.S. doesn't develop such a system first, we will be importing it from another country! Let's not waste this opportunity!

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