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Failures of Electrochemical Cells by Internal Precipitation

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Ceramics are currently being used in many electrochemical energy conversion and storage systems. These include solid oxide fuel cells (SOFC), solid oxide electrolyzer cells (SOEC), oxygen separation membranes, hydrogen separation membranes, synthesis of gaseous and liquid fuels by electrolysis, alkali metal batteries and alkali metal thermoelectric generators, to name a few. These devices are based on either anion conducting electrolytes or cation conducting electrolytes. The devices operate over a wide range of temperatures, from room temperature to 1000^{o}C, and under harsh environmental conditions. Fundamental physical, chemical and mechanical properties, which can depend upon materials composition and microstructure, dictate the durability of these materials in the applications environment. A unique attribute is that small changes in electrochemical properties can substantially influence their mechanical durability. Failure of these materials in applications often involves fracture or delamination, similar to many applications of structural ceramics in engineering applications. Yet, the mode of failure is almost always quite different from that typically encountered in applications involving structural ceramics. For example, in electrochemical systems failure often involves slow crack growth under electrochemical device operating conditions. Failures often occur by the precipitation of electrically neutral species corresponding to the mobile ion. The precipitated neutral species may be an electrical insulator (oxygen gas) or an electrical conductor (lithium or sodium metal). The mode of failure is very different in the two cases. The role of physical, chemical and electrical properties on durability of such ceramics in electrochemical systems will be discussed and contrasted with applications in which the load is purely mechanical. Fracture mechanics under remote load will be compared and contrasted with fracture mechanics under internally generated loads. Experimental results will be presented on oxygen ion conductors.

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