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A Path-Independent Integral for Fracture of Solids under Combined Electrochemical and Mechanical Loadings

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Abstract

In this study, we first demonstrate that the *J*-integral in classical linear elasticity becomes path-dependent when the solid is subjected to combined electrical, chemical and mechanical loadings. We then construct an electro-chemo-mechanical *J*-integral that is path-independent under such combined multiple driving forces. Further, we show that this electro-chemo-mechanical *J*-integral represents the rate at which the grand potential releases per unit crack growth. As an example, the path-independent nature of the electro-chemo-mechanical *J*-integral is demonstrated by solving the problem of a thin elastic film delaminated from a thick elastic substrate.

1. Introduction

Solid state diffusion under both chemical and mechanical driving forces occurs in a number material systems used in energy conversion and storage devices such as fuel cells and batteries. Under such conditions, magnitude of the stress often exceeds that caused by the mechanical driving force alone. Therefore, to design reliable energy conversion and storage systems, the synergetic effects of mechanical and chemical (or electrochemical) driving force must be understood.

The earlier work on solid state diffusion in metallic system by Larche and Cahn (1973) established the general thermodynamic framework for metallic systems. Based on this framework, Larche and Cahn have studied a number of material science and engineering problems (Larche and Cahn 1973, Larche and Cahn 1982, Larche and Cahn 1985, Larche and Cahn 1987, Larche and Cahn 1992). Following Larche and Cahn's approach, Swaminathan and

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