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Mixed Finite Element Approach for Semiconductor Structures

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ABSTRACT

Compared to piezoelectric effects restricted to noncentrosymmetric crystalline structures, flexoelectric effects exist universally in all crystalline structures [1,2]. Meanwhile, some crystals, say silicon, are also semiconductive, which raises interest in studying the interactions between mechanical fields and mobile charges in semiconductors with consideration of piezoelectricity or flexoelectricity [3,4]. In order to explain these coupling effects, macroscopic theories on elastic semiconductors considering piezoelectricity or flexoelectricity were proposed by Yang and co-authors [5,6]. For piezoelectric semiconductors, the formulation of finite elements is relatively straightforward since the governing partial derivative equation (PDE) is twice-order. As for elastic semiconductors with consideration of flexoelectricity, it is more challenging to formulate its finite element due to the strain gradients in the constitutive relations making the governing PDE fourth-order. For the fourth-order PDE, C^1 continuity is required for the displacement tensor when we use traditional finite elements (FEs) for the numerical solution, which brings difficulties in the FE implementation [7,8]. In the present work, instead of using C^1 elements, we develop an alternative mixed finite element with C^0 continuity for solving the problem. The convergency and accuracy of the developed element are verified, respectively. The validated mixed FE method is then used to study the problem of an infinite-length tube with an axisymmetric cross section. Our FE methods provide a tool for exploring the coupling effects in elastic semiconductors.

KEYWORDS

Piezoelectricity; flexoelectricity; semiconductors; mixed finite elements

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