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Research Highlights

Multiferroic and Magneto-electro-elastic Materials

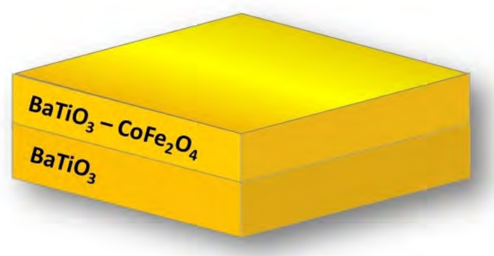
Multiferroic and magneto-electro-elastic (MEE) materials belong to the category of multi-phase materials where different phases within the materials including elastic, electric, and magnetic ones can interact for the optimal response. These materials are usually composites made of multi-phases or laminae and exhibit magnetoelectric (ME) coupling effect that is not present in the single-phase piezoelectric (PE) or piezomagnetic (PM) material. The research on MEE materials started from 1970s and the development of MEEs picked up the pace since the production of high-quality single crystals as well as the improvement of techniques of thin-film growth. Theories and computational analyses have also helped to understand the coupling among elastic, electric, and magnetic orderings.

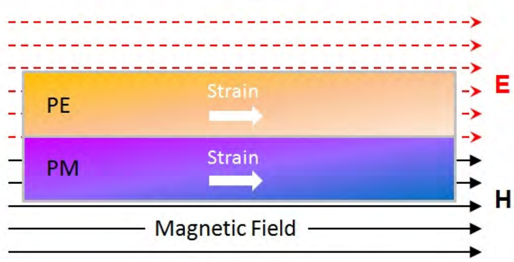
The goal is to gain more understanding of the mechanics and physics of MEE materials and structures. In particular, we respond to the key question that how electrical charge on the dislocation core can affect fields in PE and MEE bimaterials. We have already presented the problem of surface loading on MEE halfspace (read more). Recently, we have developed an analytical method in order to analyze the fields produced by 3D dislocations in MEE bimaterials in which the materials are homogeneous and of general anisotropy (read more). The main objective is to understand the effect of dislocations with electrical charge on the mechanical and electric fields.

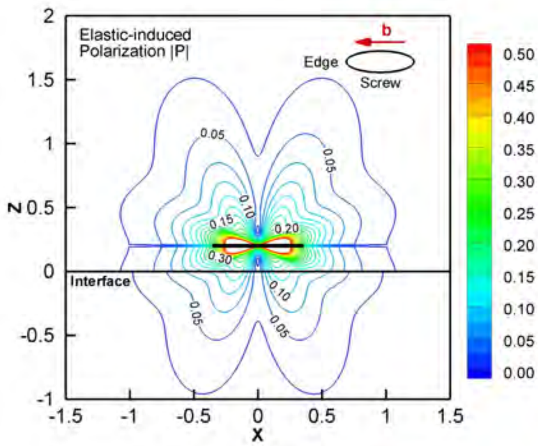
Dislocations in PE and MEE Materials

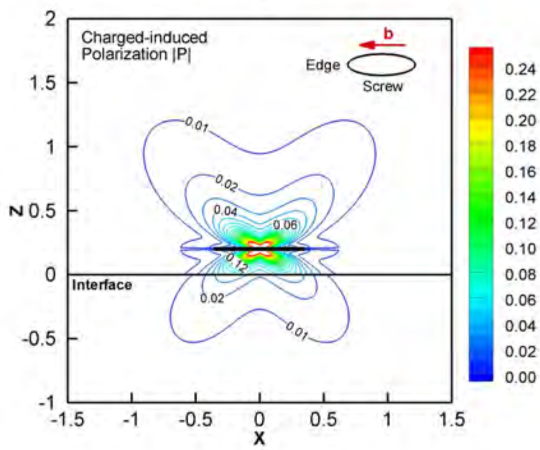
Dislocation in MEE Bimaterials

The coupling fields in MEE materials can transfer through crystal's interfacial and grain boundaries confirming that the interface have great influence on the properties of MEE structures. Accordingly, MEE devices usually contain multi-phase or laminate crystal structures in which dislocations are common defects. The fields of dislocations and fracture in bimaterials are fundamental to understand the interaction between a dislocation/crack and the interface in composites or heterostructures. We develop the formulae and methods to analyze the coupled fields induced by an arbitrarily shaped 3D dislocation loop in general anisotropic magneto-electro-elastic bimaterials (read more).







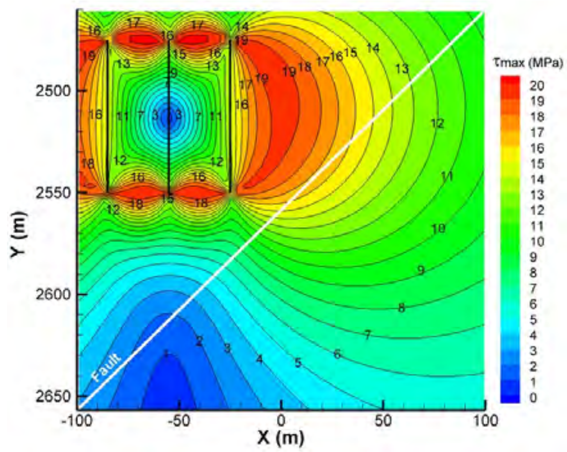


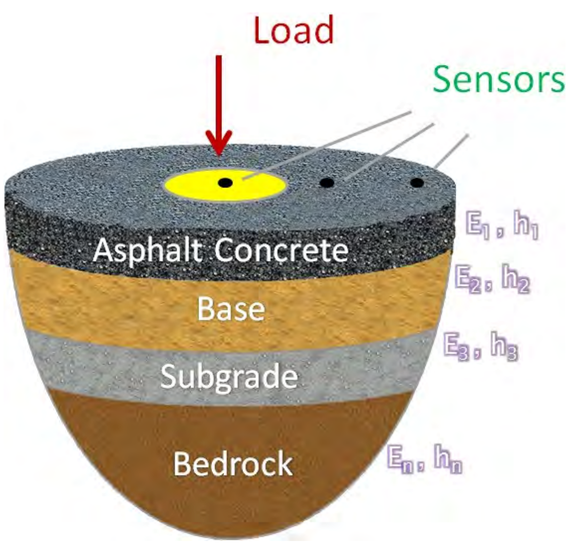
Charged Dislocation in PE Bimaterials

Composite materials consisting of piezoelectric components are categorized into the multiferroic materials which display interesting coupling effects among mechanical and electric fields. It is essential to investigate the fundamental behavior of dislocation since it directly affects the mechanical and physical properties of materials. Besides the local deformation in the crystal lattice induced by various types of dislocations, the accumulation of charge along the dislocation lines affect the transport phenomena by dislocation-electron interaction. Crystal lattice defects including dislocations, disclinations, and twinning are created due to the lattice mismatch during the epitaxial growth of semiconducting materials into layered structures. Misfit dislocations (MD) and threading dislocations (TD) as common defects in AlGaN/GaN heterostructures are under intense experimental and analytical research. Dislocations in AlGaN/GaN heterostructures can be also highly charged and act as lines of Coulomb scattering centers, reducing the carrier mobility, and degrading the device performance. We present the importance of charge and its effect on the elastic and electric fields without compromising the interface effect. The presented analytical solution are practical not only to the problems in physics but also to the ones in applied mechanics and materials.

Cracks in Elastic Halfspace

It is well-known that during hydraulic fracturing, many vertical cracks will be created. If there is a natural fault nearby, it would be mostly desirable to know how these new cracks would affect the stress field around the fault. We present an exact closed-form solution for the stress perturbation around a fault in a half plane induced by nearby multiple hydraulic cracks. The solution is based on the concentrated displacement discontinuity in the half plane which can be easily coded for fast and accurate calculations. The contribution from in-situ stresses on the fault is also determined in terms of Mohr-Coulomb criterion.



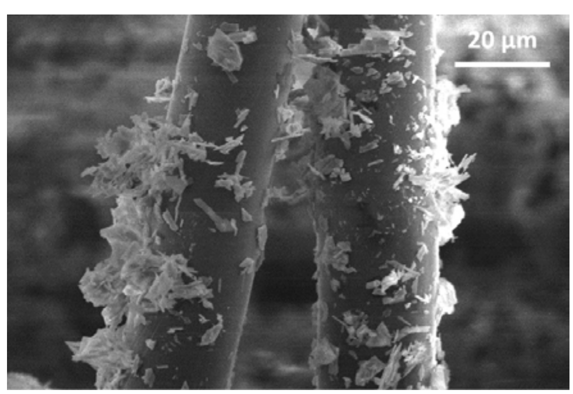


Inverse Calculation of Material Properties

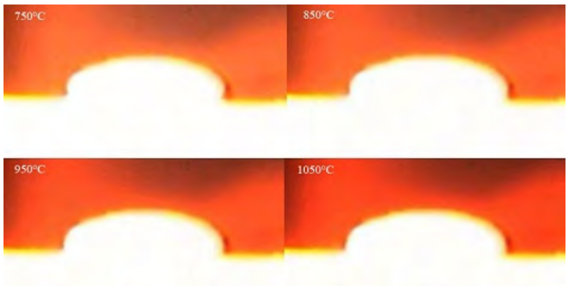
Solutions to the problem of surface loading over an elastic halfspace or layered structures are important to various technological and scientific fields including pavement engineering. In addition, the importance of backcalculation methods in the analysis of elastic modulus in pavement engineering has been confirmed for a few decades. We have developed backcalculation methods to determine the pavement layer elastic modulus and thickness based on genetic algorithm (read more) and system identification methods. A simple, user-friendly, comprehensive program called BackGentetic3D has also been developed using GA-based backcalculation method which can be utilized for any layered structures in science and engineering. Please see the detailed report and the corresponding backcalculation method.

Fiber Reinforced Composite Materials

Fiber reinforced composites are receiving numerous engineering applications due to their simple preparation, lightness, high strength, and high fracture toughness. The fiber/matrix interface characteristics are of crucial importance to the mechanical behavior of fiber composites. Based on the shear lag analysis at the fiber/matrix interface, we present an analytical approach for the tensile strength of randomly oriented fiber gypsum composites. Read more about bonding study in anodized aluminum short fiber gypsum composites. Read more about tensile strength modeling of gypsum composites reinforced with Polypropylene (PP) and Kevlar fibers.



Wetting in Polycrystalline Alumina



Wetting between metals and ceramics is of crucial importance to material joining and metal-matrix composite (MMC) production. Sessile drop method is one of the major techniques used on the investigation of metal-ceramic wetting. We investigate the contact angle of pure aluminum and aluminum-magnesium alloys on the surface of the polycrystalline alumina substrate in a broad temperature range (750 to 1100ºC). Read more about Al/Alumina wetting and Al-Mg/Alumina wetting.