Size-dependent behavior in nano-dielectric Bernoulli-Euler beam

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Summary Size-dependent behavior of Bernoulli-Euler dielectric nanobeam taking into account the non-local elasticity, the flexoelectric effect and surface stress is presented. A Cantilever beam problem is solved using the new model. The normalized deflection of the beam is shown in size-dependent and the effect of the flexoelectric is discussed.

Introduction

The development of nanotechnology brings thinner and thinner dielectric films and nanosized electronic devices. Due to the new electrical, optical, chimerical and mechanical properties, Nanoelectromechanical systems have the potential to offer even better applications compared to Microelectromechanical systems [1]. The higher-order gradient elasticity in elastic materials are developed to describe the micro behavior [2], however, dielectric nanomaterials with gradient theory are lacking and important due to the wide applications of these materials in engineering. It is well known that both gradient theory and surface theory can capture the size-dependent behavior in micro- and nano-structures [3-4]. Unlike their bulk material properties, Nano dielectric materials are often exhibit size-dependent properties when the crucial dimensions approach nanometers [1-4]. The Bernoulli-Euler dielectric nanobeam with the electrostatic force, the flexoelectric effect and non-local elasticity/surface stress is studied and the size-dependent behavior of nano dielectric structures is discussed.

Formulation

Using the variational of the electric Gibbs free energy density for a nano dielectric material, the governing equations and boundary conditions can be derived. The one-dimensional piezoelectric beam problem is then solved using Bernoulli-Euler beam theory.

Electrostatic force in nanobeam

We studied the electrostatic force on a piezoelectric nanobeam and shown that the electrostatic force effect is very strong when the beam thickness is small, but can be neglected when the beam thickness is large. However, the higher-order strain gradient and surface stress are not taking into account.

Size-dependent behavior based on strain gradient theory

It is well accepted in elasticity that gradient theory can capture the size-dependent behavior in micro- and nano-scale structures. Based on strain gradient elasticity theory, higher-order strain gradient beam theory in nano dielectric materials are discussed [4-5]. The size-dependent in Bernoulli-Euler nanobeam is investigated under different electric assumption. For open circular condition, we showed that the size-dependent behavior in deflection of a cantilever beam. The flexoelectric effect enhanced the effective electromechanical coupling coefficient (EMCC). We also showed the deflection of a cantilever changed when external voltage applied due to the flexoelectric effect.

Surface effect

In nanoscale, the surface of the structure becomes important. The surface effect become domain and should be appropriate considered. Elastic continuum beam with surface stress have been done in many papers. We studied the influence of the residual surface stress on the deflection of a piezoelectric nanobeam and on the effective electromechanically coupling coefficient (EMCC). The normalized deflection is size-dependent in nanoscale and the EMCC is much larger than that of the bulk materials when the beam thickness is small.

Conclusions

The Size-dependent behavior in nano dielectric Bernoulli-Euler beam based on the strain gradient theory and surface theory is studied. The normalized deflection of a cantilever beam is shown size-dependent of the thickness. When the beam thickness is small, the strain gradient is strong and becomes important, as well as the residual surface stress, the deflection of the beam taking account into the strain gradient/ surface stress is smaller than that of classical beam theory. The electromechanical coupling coefficient is enhanced a lot due to the flexoelectric effect/ surface stress in nano piezoelectric structures.

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