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Size-dependent vibration analysis of viscoelastic nanocrystalline silicon nanobeams with porosities based on a higher order refined beam theory

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Abstract

Based on a higher order refined beam model, damping vibration analysis of multi-phase viscoelastic nanocrystalline nanobeams on visco-Pasternak foundation in carried out accounting for nano-grains and nano-voids sizes. For the first time, a contribution of nonlocal and couple stress effects is applied for damping vibration analysis of nanocrystalline nanobeams. In fact, couple stress theory considers grains micro-rotations. While, nonlocal elasticity theory considers long-range interactions between the particles. Viscoelastic medium is described as infinite parallel springs as well as shear and viscous layers. Hamilton's principle is employed to derive the governing equations and the related boundary conditions which are solved applying an analytical approach. The frequencies are compared with those of nonlocal and couple stress based beams. It is observed that damping frequencies of a nanocrystalline nanobeam are significantly influenced by the grain size, grain rotations, porosities, interface, damping coefficient, surface energy, nonlocality and structural damping.

Keywords: Free Vibration; Higher-order theory; Nanocrystalline nanobeam; Nonlocal couple stress theory

1. Introduction

Lately, nanotechnology and nanostructures have gained an unbelievable role in the modern engineering and the rate of nanostructures' employment in various micro/nano electro-mechanical-systems (MEMS/NEMS) is rising with a high speed [1-4]. Such micro/nano structural systems are constructed from nanostructured materials due to possessing small size. It is known that nanostructured materials such as nanocrystalline materials (NcMs) and nanoparticle composites (NpCs) have an inhomogeneous structure and their properties are significantly influenced by the essence of their material structure [5, 6]. In fact, nanocrystalline materials are multi-phase composites consist of grain phase, porosities and interface phase. In NcMs, several atoms are separated from the grains and create a new phase which is called as the interface. The interface phase shows a softening impact on the structure by reducing the elastic moduli [7, 8]. Also, properties of nanocrystalline materials depend on the grain and porosity size which can change from 0.5 to 100 nm [9]. Recently, some physical phenomena have been reported in micro/nano scale structures such as the translation and rotation of grains or crystals