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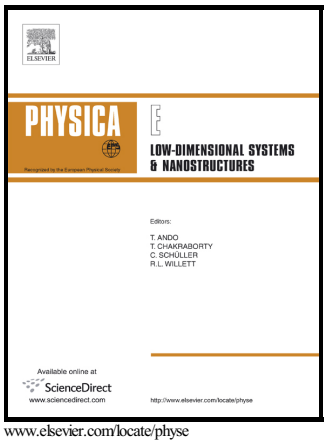

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Thermal Effects on Mass Detection Sensitivity of Carbon Nanotube Resonators in Nonlinear Oscillation Regime

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Abstract

A mass sensor using a nano-resonator has high detection sensitivity, and mass sensitivity is higher with smaller resonators. Therefore, carbon nanotubes (CNTs) are the ultimate materials for these applications and have been actively studied. In particular, CNT-based nanomechanical devices may experience high temperatures that lead to thermal expansion and residual stress in devices, which affects the device reliability. In this letter, to demonstrate the influence of the temperature change (i.e., thermal effect) on the mass detection sensitivity of CNT-based mass sensor, dynamic analysis is carried out for a CNT resonator with thermal effects in both linear and nonlinear oscillation regimes. Based on the continuum mechanics model, the analytical solution method with an assumed deflection eigenmode is applied to solve the nonlinear differential equation which involves the von Karman nonlinear strain-displacement relation and the additional axial force associated with thermal effects. A thermal effect on the fundamental resonance behavior and resonance frequency shift due to adsorbed mas, i.e., mass detection sensitivity, is examined in high-temperature environment. Results indicate a valid improvement of fundamental resonance frequency by using nonlinear oscillation in a thermal environment. In both linear and nonlinear oscillation regimes, the mass detection sensitivity becomes worse due to the increasing of temperature in a high-temperature environment. The thermal effect on the detection sensitivity is less effective in the nonlinear oscillation regime. It is concluded that a temperature change of a mass sensor with a CNT-based resonator can be utilized to enhance the detection sensitivity depending on the CNT length, linear/nonlinear oscillation behaviors, and the thermal environment.

Keywords

Thermal effect, Carbon nanotube (CNT), Nonlinear oscillation, Mass sensor, Temperature change, Mass detection sensitivity

1. Introduction

Carbon nanotubes (CNTs) have attracted growing interest worldwide ever since their discovery and they are being studied as a promising material owing to their superior mechanical and electrical properties [1–3]. These remarkable properties are result of the large aspect ratio, low density, high