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A Stochastic Multi-Scale Approach for the Modeling of Thermo-Elastic Damping in Micro-Resonators

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Abstract

The aim of this work is to study the thermo-elastic quality factor (Q) of micro-resonators with a stochastic multi-scale approach. In the design of high-Q micro-resonators, thermo-elastic damping is one of the major dissipation mechanisms, which may have detrimental effects on the quality factor, and has to be predicted accurately. Since material uncertainties are inherent to and unavoidable in micro-electromechanical systems (MEMS), the effects of those variations have to be considered in the modeling in order to ensure the required MEMS performance. To this end, a coupled thermo-mechanical stochastic multi-scale approach is developed in this paper. Thermo-mechanical micro-models of polycrystalline materials are used to represent micro-structure realizations. A computational homogenization procedure is then applied on these statistical volume elements to obtain the stochastic characterizations of the elasticity tensor, thermal expansion, and conductivity tensors at the meso-scale. Spatially correlated meso-scale random fields can thus be generated to represent the stochastic behavior of the homogenized material properties. Finally, the distribution of the thermo-elastic quality factor of MEMS resonators is studied through a stochastic finite element method using as input the generated stochastic random field.

Keywords: Thermo-elasticity, Quality factor, Stochastic Multi-scale, MEMS, polycrystalline

1. Introduction

In the micro-electromechanical systems (MEMS) community, there are increasing demands in developing reliable micro-structures with very high quality factors (Q). These micro-structures constitute the essential active part of applications such as resonant sensors and RF-MEMS filters, for which increasing the sensitivity and resolution of the devices is a critical issue. In order to obtain high-Q micro-resonators, all dissipation mechanisms that contribute to decreasing the quality factor have to be identified and well considered at the

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