Multiple internal resonances and impacting dynamics of micromachined arch resonators

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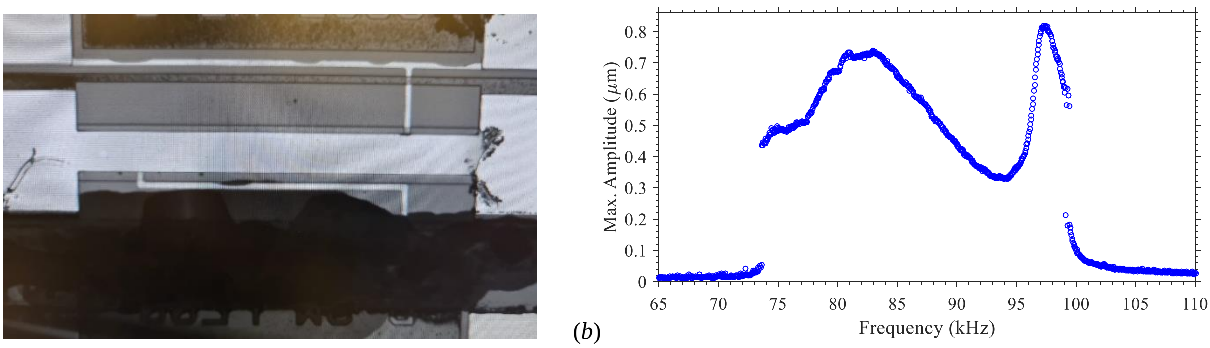
Abstract. The present study investigates the experimental response of an electrically actuated microbeam-based MEMS resonator with arched configuration of concave surface. The resonator is excited using an antisymmetric partial electrode. Forward and backward frequency sweeps are acquired. The device exhibits M-shaped 2:1 internal resonance between the first (first symmetric) and the second (first antisymmetric) mode, showing softening and hardening bending behaviour. We observe the profound coupling induced by the 2:1 internal resonance between these modes. As increasing the oscillations amplitude, the microbeam impacts with the substrate. A specially deposited dielectric layer allows the system to impact with the substrate while preventing electrical shorts. Driven by the impacts, the experimental response shows the activation of additional internal resonances, where the two successive higher-order modes are involved and combined with the main M-shaped 2:1 internal resonance. The experimental dynamics are analysed extensively to investigate the underlying physical phenomena arising in the MEMS response.

Introduction

Specific relationships among the natural frequencies can induce multimode nonlinear interactions [1]. This complexity offers outstanding capabilities for MEMS/NEMS applications [2]. The possibility of activating internal resonances by driving the system into impacts has been recently investigated [3]. Motivated by the increasing interest in operating devices in regime of internal resonance, in the present study we experimentally and theoretically analyse the activation of multiple internal resonances in an arched MEMS device electrically actuated.

(*a*) 

(*b*)

Figure 1: (*a*) The MEMS device (optical image). (*b*) Experimental frequency response diagram (amplitude versus drive frequency), at V_{DC} = 15.0 V and V_{AC} = 28.6 V (backward sweep).

Results and discussion

The MEMS device experimentally tested is shown in Fig. 1(*a*). It consists of an electrically actuated clamped-clamped microbeam with arched configuration of concave surface. This configuration is a consequence of imperfections due to the fabrication process and residual stress. The device presents a dielectric layer to prevent short-circuiting in case of impact with the substrate. Experimental frequency sweeps are acquired, Fig. 1(*b*). The experimental response exhibits M-shaped 2:1 internal resonance between the first and second modes. As increasing the oscillations amplitude, the microbeam impacts with the substrate. Due to the impacts, additional resonances related to higher-order modes get activated, which are coupled among each other and with the principal M-shaped 2:1 internal resonance. Simulations are developed based on Galerkin reduced-order model accounting for the modes involved in the multiple internal resonances experimentally observed. To model impacts, the substrate is assumed as a nonlinear elastic foundation, which is described in the framework of the Hertz impact model and Hunt-Crossley damping model [3]. A deep analytical study is developed to capture the characteristics of the MEMS behaviour and to characterise the potential rich and complex dynamics.

References

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