8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

DESIGN OF NONLINEAR MICROSWITCHES FOR RADIOFREQUENCY APPLICATIONS

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Key Words: *RF-MEMS, electromechanical coupling, structural and geometrical nonlinearities, mechanical coupling, FEM, BEM .*

ABSTRACT

Among the most popular layouts of RF-MEMS used in radio frequency applications, double clamped microbeams are used to build microswitches, microresonators and varactors in reconfigurable wireless terminals [1-4]. Although beam structure is a paradigm of classic solid mechanics [5], in the specialized literature some aspects of the coupling effects occurring in these microsystems are neglected. Actually, in double clamped microbeam the nonlinear electromechanical coupling between mechanical displacement and voltage often adds to the mechanical coupling occurring between the axial and flexural behaviours [6-9]. The latter is usually assumed to be effective only for large displacements [6-9], but it leads to a structural nonlinearity even for very small values. A stiffening effect can be found on the microdevice when a residual tensile stress is imposed by microfabrication. This phenomenon depends on the microbeam stretching in bending and belongs the so-called geometrical nonlinearities. This study implemented FEM and BEM numerical methods to analyse the multiple nonlinear and coupled problem. The solution time is usually long, because of the mesh morphing operation applied in the dielectric field to avoid elements distortion. Special finite elements were used to discretize the beam. They allowed decreasing the computational effort of the sequential solution [10]. Stiffness matrix included several terms. Structural stiffness, stiffening effect of the residual stresses imposed by the microfabrication process and geometrical nonlinearity were all considered. A non uniform residual stress distribution across the microbeam section was even modelled, although it looked very hard measuring this phenomenon on the experimental microspecimens.
Sometimes the assumption of perfect double clamped microbeam is insufficient to predict the actual interaction among microbeam, anchors and ground electrode. In this case the numerical approach helps the designer to investigate the effects on the electromechanical forces of the actual geometries of anchors and electrode. Two and three dimensional models were implemented. Authors developed original subroutines in MATLAB© environment, but a numerical validation of results was performed in the ANSYS© code. Solutions where the structure was discretized by FEM and the dielectric material by either FEM or BEM were compared. A sensitivity analysis investigated the role on the static and dynamic behaviours of some design parameters,

including the effective gap and the geometry of the ground electrode. A preliminary experimental validation on golden microswitches was performed. It was found that geometrical nonlinearity is very effective in determining the pull-in condition and the frequency response of the RF-MEMS. The original numerical approach, based on a special finite beam element described in [10] demonstrated to be suitable to implement compact models, to decrease the iterations of the sequential solution and to deal simultaneously with the electromechanical and geometrical nonlinearities.

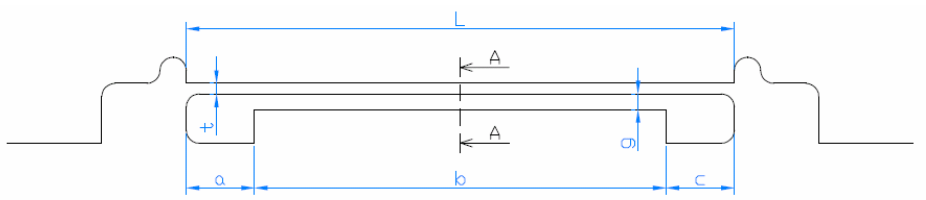

Figure 1: Double clamped microswitch tested in experimental validation.

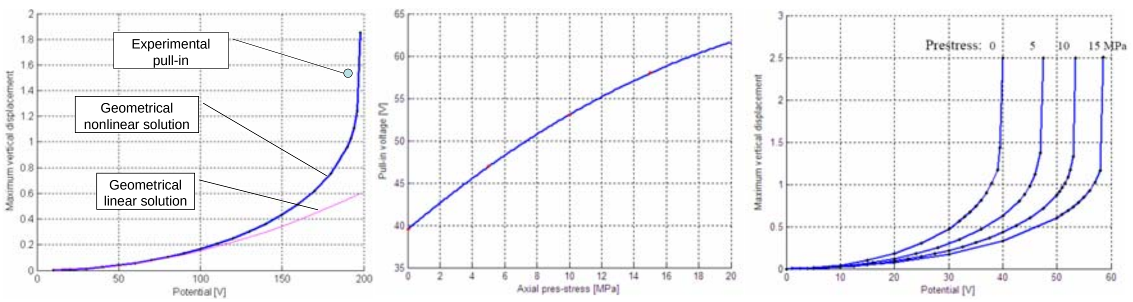

Figure 2: Examples of numerical analysis of microswitch behaviour: pull-in curve for specimen 1-7 (a) dependence of pull-in on residual pre-stress in specimen 1-5 (b) and (c).

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