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IMPROVEMENTS IN ACCURACY OF RF-MEMS ELECTROMECHANICAL SIMULATION WITHIN CADENCE©

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ABSTRACT

In recent years employment of MEMS technology (MicroElectroMechanical-Systems) in designing RF (Radio Frequency) systems is increasingly drawing the attention of the Scientific Community. This is because of the well-known remarkable performances achievable with MEMS implementation of RF components (such as variable capacitors, inductors and switches) if compared with the ones realized in CMOS technology (e.g. very high Q-Factor, wide capacitance tuning-ratio, high isolation and so on) [1]. Nevertheless, exploitation of RF-MEMS based solutions poses a few issues concerning the design flow to be adopted in addressing the requirements for a specific project. Indeed, modelling of MEMS devices involves the coupling of different physical domains (electrical and mechanical), which usually cannot be managed by commercial IC (Integrated Circuit) development tools. Because of the considerations mentioned above, the authors developed a library of compact models by means of the VerilogA© programming language within Cadence© environment (for the Spectre© circuit simulator [2]) whose features and capabilities have been already presented [3, 4].

MEMS COMPACT MODEL LIBRARY

Proper assembling of elementary components included in the library (like flexible straight beams and air gaps) allows the fast and accurate simulation of MEMS devices with complex geometries. An example is reported in Figure 1 and refers to a toggle-switch, which is a particular implementation of switch with a double actuation mechanism [5]. First of all the structure is split in half because of its symmetry and suitable symmetry conditions are applied to the symmetry plane, achieving a large reduction of the computational complexity. The structure was implemented with the compact models available in the library (the Cadence© schematic is shown in Figure 1-b) and validated with a FEM simulation performed with COVENTOR™ (see Figure 1-a). Vertical displacement of the central plate, both for the downward and upward movement, is predicted very accurately by a DC simulation in Spectre© as shown in Figure 1-c and Figure 1-d. A further step consists in the validation of the MEMS compact models against experimental data. To this purpose, the static and dynamic behaviour (i.e. transient response) of an RF-MEMS varactor is simulated within Spectre© and compared with experimental data. Measurements are performed with a Veeco™ WYKO NT1100 DMEMS dynamic optical profilometer, based on interferometry and stroboscopic illumination of a periodic device movement. The 3D profile of the characterized variable capacitor is shown in Figure 2-a. It is based on a central rigid plate suspended by four serpentine-like flexible structures.

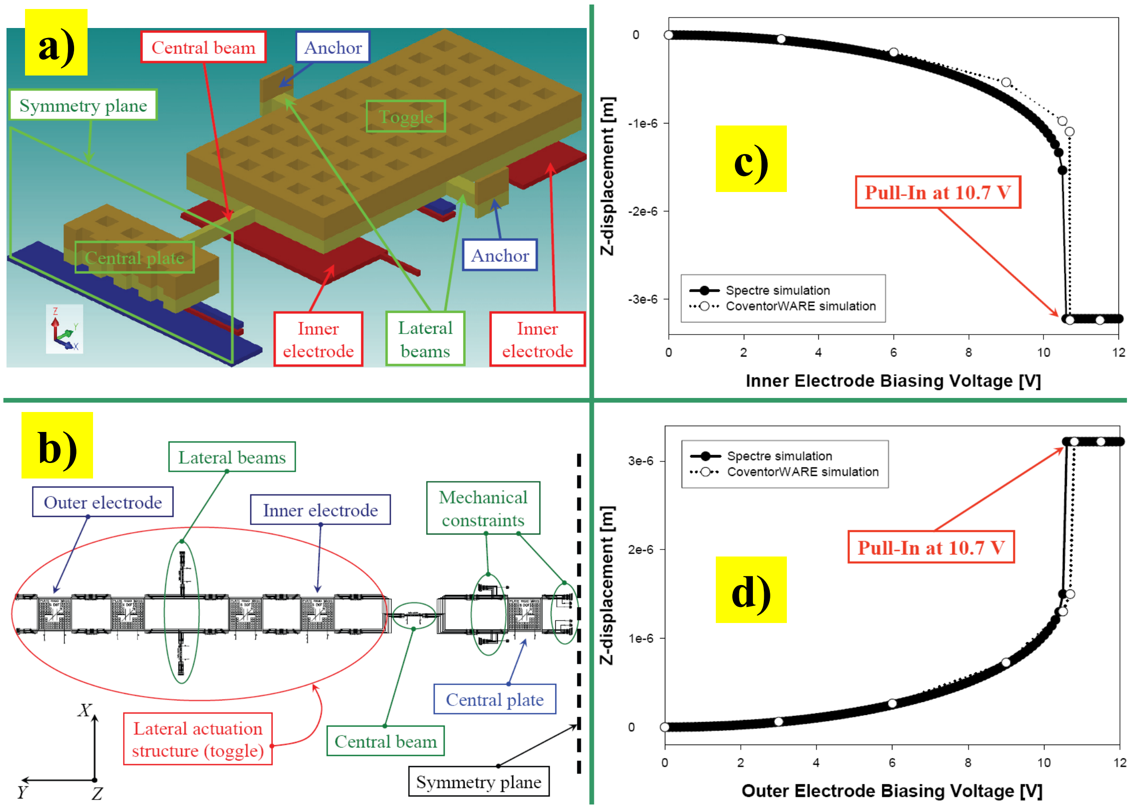

Figure 1. MEMS toggle-switch schematic in Coventor™ (a) and in Cadence© (b). Pull-in of the lateral actuation structure is predicted with large accuracy by the Spectre© simulation both when the inner (c) and outer (d) electrodes are biased.

The experimental vs. simulated pull-in/pull-out characteristic is shown in Figure 2-b showing a very good agreement of the two characteristics [6]. The RF-MEMS variable capacitor was then characterized in transient condition. A squared voltage stimulus from 0V to 4V, with a period of 2.5 msec (400 Hz), is applied to the suspended plate (50 % duty-cycle). Since the variable capacitor actuation voltage is 4.9 V the plate does not collapse on the substrate during this analysis. Transient simulated response compares well to the experimental data for the same analysis as reported in Figure 2-c. This type of analysis is rather critical as it involves the whole behaviour of the intrinsic non-linear electromechanical model, also including the inertia and the viscous damping effects. The same analysis is repeated with an applied voltage of 5 V, i.e. beyond the pull-in voltage. In this case the suspended plate collapses onto the underlying electrode, as shown in the plot of Figure 2-d.

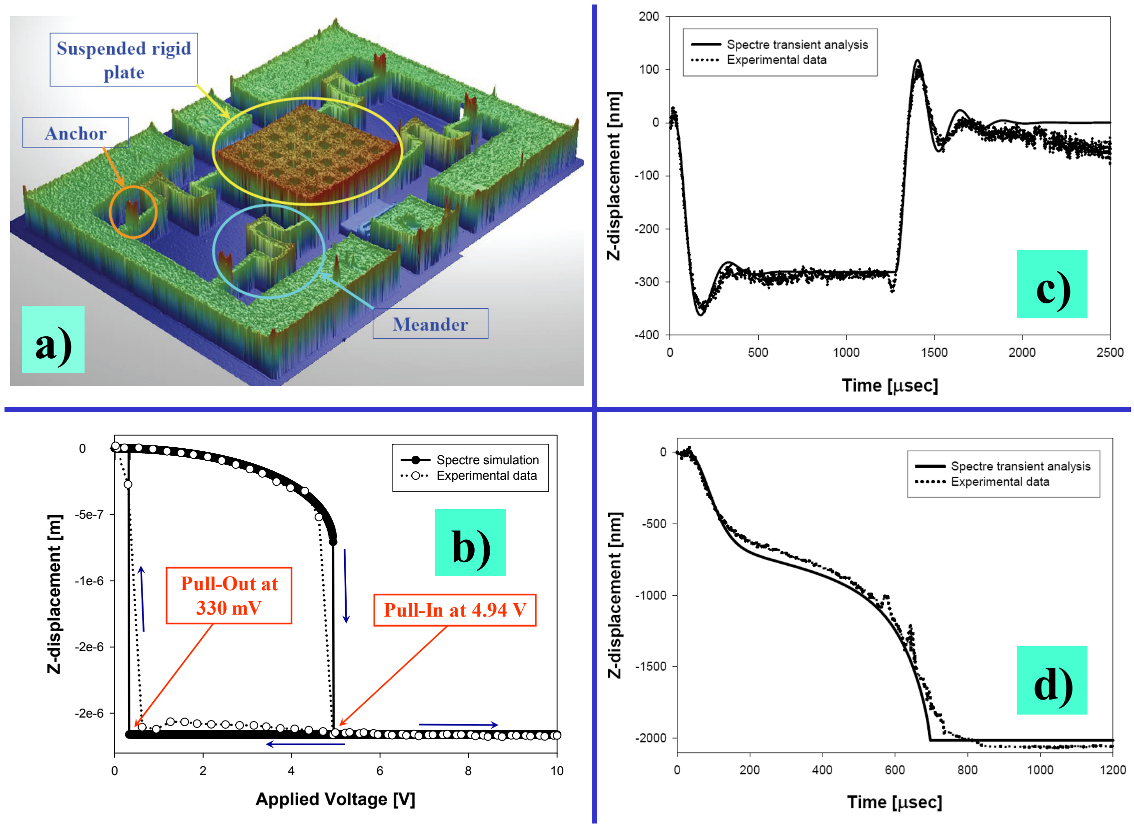

Figure 2. 3D view of the RF-MEMS variable capacitor fabricated in FBK-irst technology (a). Static pull-in/pull-out simulated characteristic compares well with the experimental one (b). The same consideration is valid for the transient characteristic both with a peak bias voltaGe below (c) and beyond the pull-in (d).

CONCLUSIONS

In this work we presented our approach in simulation of RF-MEMS devices based on a compact model library written in VerilogA© language and implemented within the Cadence© IC development environment. Elementary models were validateD both against FEM simulation and static/dynamic experimental data collected with an optical profiling system. Extensions of the mechanical models implemented in the library, e.g. accounting for geometric non-linearity when flexible beams undergo large deformations, have been analytically developed but not yet implemented in VerilogA©. This will enable a better modeling of non-idealities linked to real devices, making the presented library more suitable for the design and electromechanical optimization of RF-MEMS devices and sub-systems fabricated in FBK Technology. Eventually, the library will also ease the work of third party designers who are not very familiar with the FBK RF-MEMS Technology.

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