Microelectronics Journal 77 (2018) 5–15

Contents lists available at ScienceDirect

Microelectronics Journal

journal homepage: www.elsevier.com/locate/mejo

Pull-in-voltage and RF analysis of MEMS based high performance capacitive shunt switch

Osor Pertin *, Kurmendra

Department of ECE, Rajiv Gandhi University, Itanagar, India

ARTICLE INFO

Keywords:
RF MEMS
Pull-in-Voltage
Bridge
S-Parameter
FOM
Static analysis
Switch

ABSTRACT

This paper presents design of a RF MEMS (Radio Frequency Micro Electro Mechanical system) capacitive shunt switch to study the switch performance which depends on various indices. To achieve high performance in the MEMS switch, the different component materials of the switch were chosen very carefully. Modeling equations were also derived for designed fixed-fixed beam of the switch considering formed capacitances in both upstate and downstate positions. The FEM simulation and accurate analytical results were obtained to study the effect of capacitance on the RF performance of the switch. The optimum dimensions were chosen for achieving a low pull in voltage as approximately 19 V for the designed switch. Static analysis confirms the optimum dimensions of the switch that provide several advantages such as high isolation, low insertion loss and low pull in voltage in the switch circuit. RF analysis study concludes that for the optimized switch provide return loss, insertion loss and isolation as −43 dB, −0.05 dB, −12 dB respectively.

1. Introduction

Recent advances in science and technology have allowed reduction in size of RF switches. RF MEMS provides for the miniaturized and efficient devices in the microwave application. One of the major applications is the RF MEMS switches [1–9]. RF MEMS switches offer many advantages over the conventional semiconductor switches [1,2]. They use mechanical movement of the structural component when actuated to achieve open circuit or close circuit in a RF transmission line. They are generally of two types- (i) DC-contact cantilever-based series switch and (ii) Capacitive contact Fixed-fixed beam based shunt switch. These switches offer low insertion loss during ON state and high isolation during OFF state of the switch, long life. The important switching parameters of the switch are transition time, switching rate, RF power handling capability etc. [5–8]. Many Researchers are working on bringing down the actuation voltage of RF MEMS switches [3,4]. Studies show that for getting low pull in voltage the best material properties should be chosen and structural parameter of the switch should also be optimized [9,10]. Sazzadur et al., demonstrated a method to calculate the pull in voltage by using a cantilevered sensing structure which collapses when electrostatic forces are applied to it [15]. Koutsoureli et al., presented an analytical model for obtaining up state capacitance voltage characteristics considering non-uniform charge and capacitance distributions [16]. Pirmoradi et al., Designed a lateral RF MEMS latching switch and actuated by electro-thermal input, the switch parameters show a better performance with latching structure [17]. Tejinder et al., presented a model and design of SP4T series-shunt switch and concluded that the MEMS shunt switches show high isolation in switch off condition [18]. Viscosity of the medium plays very important role in pressure variation on the switch. The pressure variation in the switch is directly proportional to viscosity of the medium and air gap between top and bottom electrodes. If the medium in between two electrodes is having high viscosity coefficient more stress can be developed by applying low pull in voltage [31–33]. In some articles related to MEMS switch, authors have put advantages of introducing holes on the top electrode of the switch. The results are very much acceptable because they improve the pull in voltage requirement as well as capacitance of the switch. The effect of holes with larger diameters are also investigated in the articles [34–36].

In this paper, firstly a rigorous review on MEMS capacitive shunt switch was done for selection of bridge materials as well as structures with best performance were analyzed. The bridge material was chosen as Gold as per their performance reported in the articles [19,20]. A Capacitive MEMS switch is designed and modeled with optimal geometric configuration for a low pull in voltage. Modeling of capacitance of the switch is presented for accurate calculation in the upstate and downstate position of the beam. The static and RF characteristic of the

* Corresponding author.
E-mail address: osorpertin.rgu@gmail.com (O. Pertin).

https://doi.org/10.1016/j.mejo.2018.05.001
Received 20 September 2017; Received in revised form 30 April 2018; Accepted 1 May 2018

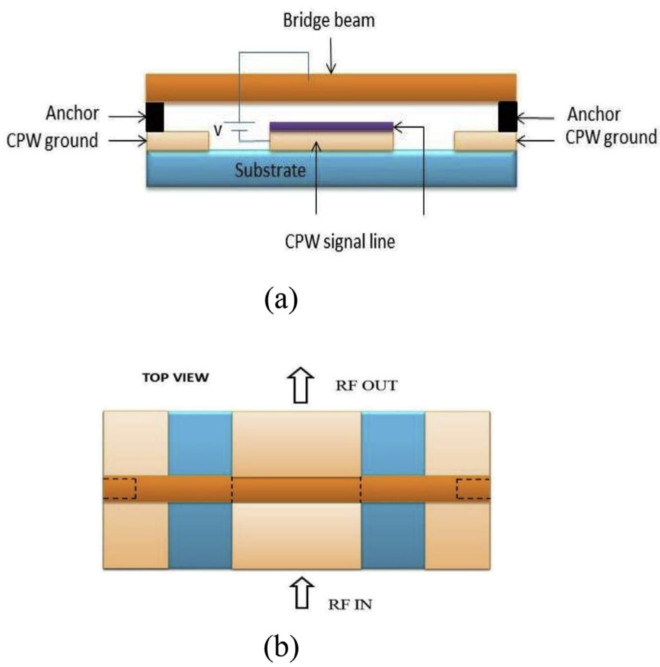

Fig. 1. Schematic of MEMS capacitive shunt switch (a) side view (b) top view.

Table 1
Geometric specification.

Notations	Value	Description
L	100[μm]	Beam length
W	5[μm]	Beam width
T	1[μm]	Beam thickness
l	50[μm]	Signal line length
w	10[μm]	Signal line width
t	1[μm]	Signal line thickness
Va	19[V]	Applied voltage
ε_0	8.854 e^{-12}[F/m]	Permitivity of free space
g	0.6[μm]	Air gap
t_d	0.4[μm]	Dielectric thickness
F_a	1.1[μN]	force
t_s	5[μm]	Substrate thickness
k	12.8[N/m]	Spring constant

Table 2
Choice of material.

Selection	Material
Fixed-Fixed Beam	Gold (Au)
Dielectric Layer	Silicon Nitride (Si_3N_4)
Coplanar Waveguide (CPW)	Gold
Substrate	Poly-Silicon
Anchor	Gold

switch is analyzed and studied using COMSOL Multiphysics Finite element method (FEM) tool.

2. Design and modeling

The MEMS capacitive shunt switch consists of a fixed-fixed beam (bridge), supported by anchors at the two ends and a Coplanar Waveguide (CPW) transmission line. The bridge is suspended over the central signal line of CPW line as shown in Fig. 1 (a). The design geometric specification for optimized pull in voltage is presented in Table 1 and material choice for the various components is presented in Table 2.

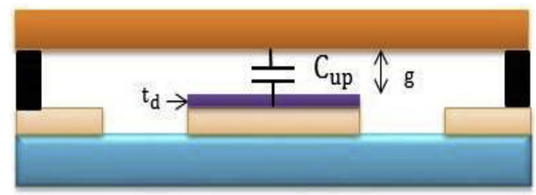

Fig. 2. Capacitance in the up-state position of MEMS capacitive shunt switch.

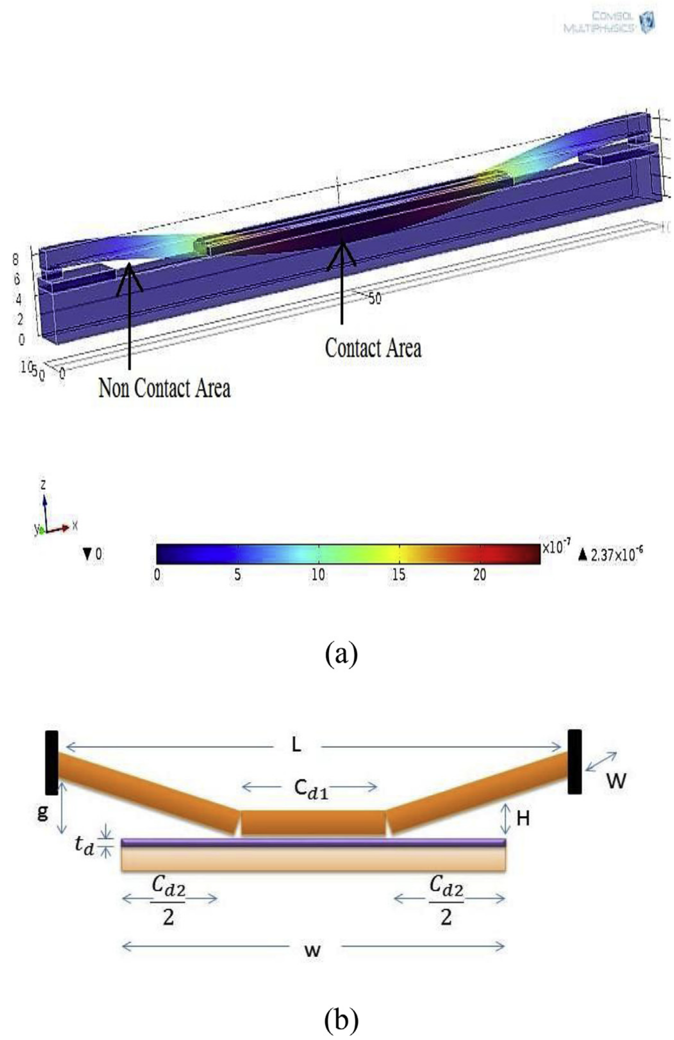

Fig. 3. (a) Simulated deformed beam showing contact and non-contact area (b) Consideration of Capacitances in down-state position.

2.1. Up-state position

Initially no control voltage is applied and the bridge is in upstate position. The RF signal transmits through the CPW signal line as shown in Fig. 1(b). The switch is said to be in the OFF state. Due to air gap and dielectric layer between the bridge and CPW signal line plate, a small capacitance is formed (Fig. 2) and can be derived as-

$$C_{up} = \frac{\varepsilon_0 \varepsilon_r wW}{\varepsilon_r g + t_d} \tag{2.1}$$

where, 'ε_r' is the dielectric permittivity 'ε_0' is the permittivity of free space, 'g' is the air gap 'w' is the CPW signal line width and 'W' is the width of the bridge beam.