DESIGN AND SIMULATION OF FLEXIBLE MEMS INTERDIGITAL CAPACITOR FOR ENERGY STORAGE SYSTEMS

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Abstract:

In this research work an actuation mechanism based on the micro electromechanical systems interdigital capacitor (IDC) for flexible substrate. This IDC model is one of the basic model which uses the principle of electrostatic and force can be generated for the capacitive sensors. This study carryout by overlapping movable and fixed comb fingers which produces an energy. The ZnO and Polyimide material based on the planar electrodes are analysed for different number of combs and gap between the fixed and movable combs using Finite Element Methods (FEM) techniques. Results are shown in the structural domain performance of an electrostatic actuation verses number of combs and displacement is related to change in the capacitance due to the comb fingers and calculated the capacitance in overlapping combs. Here Finite element method (FEM) is used to simulate the physics scenario and it is designed as three dimensional structure using COMSOL multiphysics domain. The prototype of MEMS interdigital capacitor suitable for micro energy storage devices.

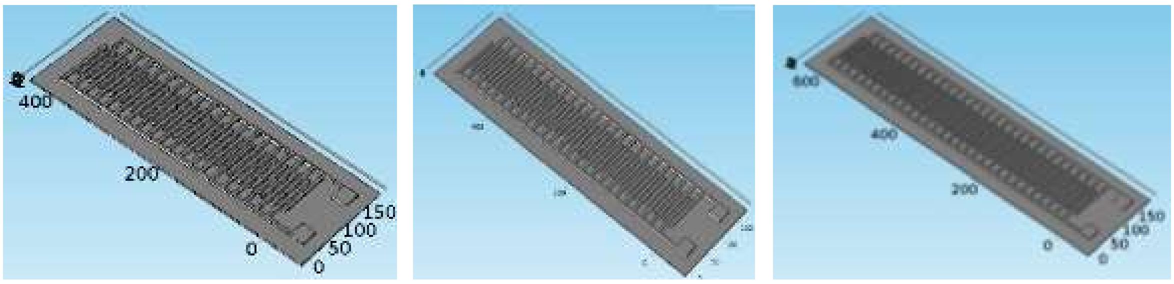
Keywords: MEMS, Interdigital Capacitor, Electrostatic actuation, FEM and Energy storage system

1. Introduction:

The comb drive is a device of the microelectromechanical systems (MEMS) interdigitated electrodes that in the most general form can be defined as micro level size of mechanical and electro-mechanical devices are silicon material made using the microfabrication methods [1]. The aim of objectives of the materials are excellent electrical and mechanical properties, which can be modified by doping but further more materials are needed for the incorporation into flexible MEMS devices. The three dimensional structure of MEMS interdigital capacitor (IDC) are designed on flexible substrate and functional material. In recent years the polymer materials have mainly used for storage devices, which can bring significant benefits from sensing to energy harvester applications [2]. Generally these systems include movable and fixed electrode excited which are led by DC and AC voltages on one or both sides [3&4]. The electric potential and distribution of the comb fingers, electrostatic force and structural problems of levitation, quadratic shaped combs of cubic electrostatic [2-8].This fundamental principle of IDC design have electrostatic force generated by overlapping combs between the movable and fixed comb fingers. The merits of energy storage device is small size, light weight, good performance, high reliability and lower cost. The three dimensional comb fingers are used to develop the MEMS interdigital capacitor based device or systems, which can bring significant benefits from sensing to energy harvester applications.

2. Methods and Materials:

The three dimensional structure of interdigital capacitor is consists of rectangular shaped comb fingers, which one fixed combs and another one movable combs and anchor pad. The voltages are applied to the prototype structure between the overlapping combs, which displacement of movable combs towards the fixed combs, generates an electrostatic force in the direction opposites to the direction along the length of the combs. Electrostatic force is generated along the overlapping comb fingers and it produces a capacitance, therefore the total capacitance is sum of capacitance contributed by neighbouring comb fingers [7]. The opposite walls of comb fingers in the overlapping region from a parallel plate capacitor contributes a capacitance C. Let C_1, C_2 be the capacitances between the fixed comb fingers and the movable comb fingers C_1 and C_2 Capacitance can be analysis of edge of the comb fingers like as fringe capacitance. This C_2 analytical estimation of fringe capacitance C2 is difficult. However, the accurate way to estimate for the fringe capacitance is by Finite Element Method (FEM), So far the fringe field capacitance should be ignored [2,5]. Here, we have IDC is designed the different number of combs 20, 25, 30 shown in Fig.1. However, the ZnO material applied to structure, substrate of polyimide materials and surrounding by air medium.



(a) 20 combs (b) 25 combs (c) 30 combs

Fig.1 Schematic layout of interdigital capacitor (IDC)

The capacitance between the movable and fixed combs can be determined as [3]

$$C(x) = \frac{N\varepsilon_0(y_0 + y)T_{th}}{g} \tag{1}$$

where, N is total number of movable comb fingers, ε_0 is the permittivity of the free space 8.85×10^{-12} F/m, y_0 is overlap comb finger, y is displacement in y direction, T_{th} is thickness of the structure layout and g is gap between the fixed and movable comb fingers on the one side.

The capacitance C is generated between overlapping comb fingers can be store the energy U is obtained as following as [3]

$$U = \frac{1}{2}CV^2 \tag{2}$$

Table 1.Important dimension of the MEMS interdigital capacitor

S.No	Part description	Designed Value
1	Structure thickness T_{th}	5μm
2	Different number of movable combs	20, 25, 30
3	Gap (g)	5μm
4	Comb finger width (W_{comb})	5 μm
5	Comb finger length (L_{comb})	100 μm
6	Overlapping combs (y_0)	70 μm
7	Anchor size width × length	35 μm ×35 μm

The three dimensional structure of interdigital capacitor can simulated through finite element method (FEM) numerical simulator in COMSOL Multiphysics 4.4 [3]. This software is adequate to both design and modelling of the various physics scenarios. This technique approximates the solution to partial differential equations by taking a model and separating it into a number of discrete smaller

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geometric entities. By solving the complex problem in MEMS area the free triangular meshing is done for 3D rectangle comb fingers geometries compute FEM analysis in an accurate manner.

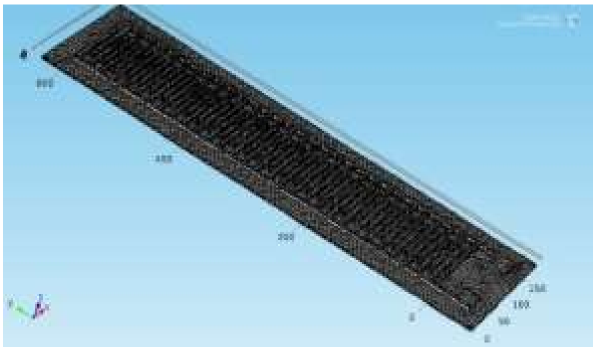
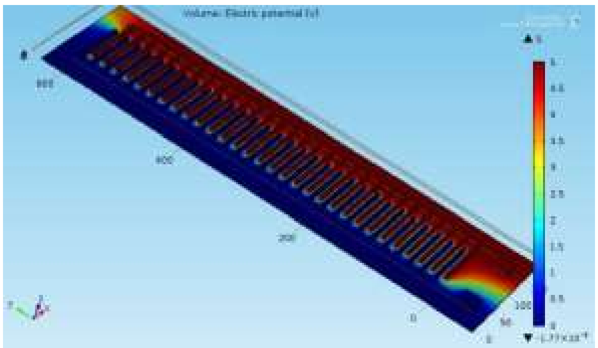


Fig.2 Triangle mesh with fine

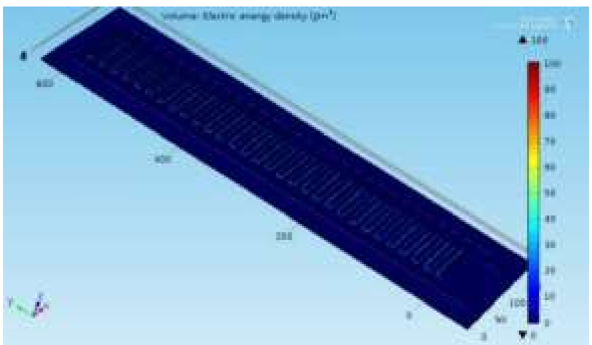
This simulations of electrostatic actuation were performed for various mesh densities for the quadratic and linear elements [7 -10]. However, the density selection of the typical values are available in COMSOL Multiphysics and it is varied from the extremely coarse to extremely fine densities. Here, Fig. 2 shows the triangle mesh with fine densities.

3. Numerical Simulation:

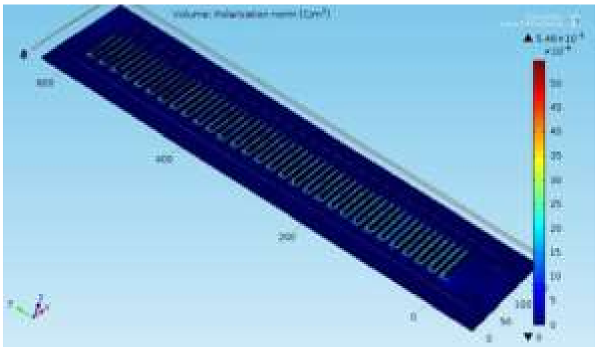
The pre-processor can create the geometries on 3D structures are designed for 20, 25 and 30 comb fingers for using the important dimension show in table 1. ZnO material can applied to 3D model, polyimide material for substrate and surrounded by an air medium. In order to study the characteristics of the MEMS IDC the electric potential have been varying 0V to 5V voltage. This research focuses the comb finger acts as an interdigital capacitor due to electrostatic actuation. Some energy stored in the comb fingers due to capacitive sensing. Here, the mentioned 3D view model of MEMS IDC based capacitive sensing shows in Fig. 3 (a) electric potential 5V, (b) electric energy density of the devices, (c) polarization norms on the combs and (d) overlapping combs displacement of the electric displacement field in interdigital capacitor.



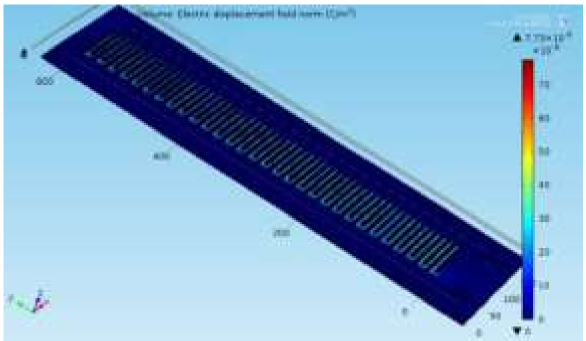
(a)



(b)



(c)



(d)

Fig. 3 (a) Electrical potential (b) Electric energy density
(c) Polarization norm (d) Electric displacement field norm

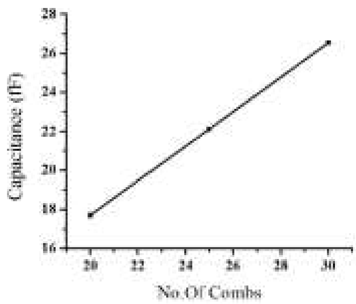
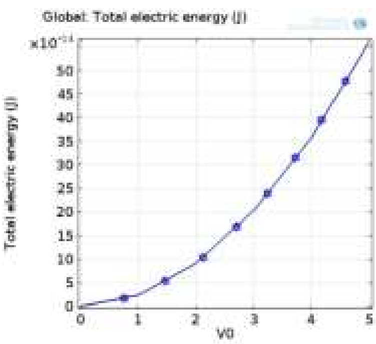
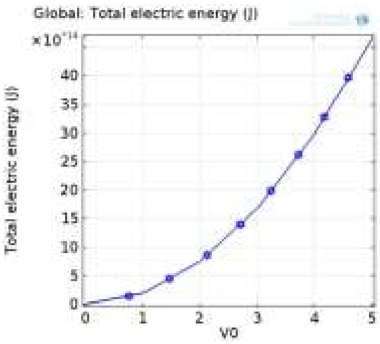


Fig.4 No.of Combs vs capacitance

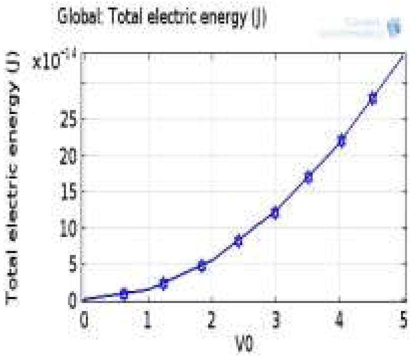
However, the capacitance analysis of the equation 1 calculated the capacitance values, that values are gradually increase in various number of comb fingers shown in fig 4.



(a) 30 combs



(b) 25 combs



(c) 20 combs

Fig.5 Applied voltages vs Total electric energy

The results shown Fig.5 for the total electric energy vs applied voltage 0V to 5V in different number of combs (20, 25, 30). This graphical representation of 30 combs IDC system is high electric displacement and electric energy than 20 and 25 combs. However, the actuation voltages is gradually increase and its produce an electric energy. Also the simulation results of voltage and electric displacement field norm is linearly increases shown in above Fig.3 and 4. The application part of this electrostatic MEMS interdigital capacitor is used an energy storage system based on capacitance with displacement.

Conclusion:

In this paper, the simulation work is primarily developed for MEMS interdigital capacitor is energy storage micro level devices. The study of electrostatic actuation based capacitance, electrical distribution of the comb fingers and total energy are analysed. This three dimensional IDC structure is produce the high capacitance values 30 movable combs and electric energy. The role of research work on FEM model offers accurate analysis using multiphysics domain and linear displacement. Therefore the MEMS interdigital capacitors are energy storage mechanism using COMSOL multiphysics.

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