CHAPTER ONE

INTRODUCTION

1.1. Research problem:

The effect of electrode position under applied voltage can result in different problems such as, The Amplitude deflection of the cantilever can reach the critical point, and even changing the mechanical properties of the vibrating structure material which result in changing the expected natural frequency of the device.

1.2. Aims and Objectives:

This research aimed to study: -

1- To study the relationship between the electrode position and Amplitude of deflection in a micro-cantilever.
2- To study the relationship between electrode position and natural frequency.
3- To study the critical points of applied voltage on the cantilever for different position of the electrode pad.
4- To study the relationship between the applied voltage and Amplitude of deflection in a micro-cantilever.

1.3. Literature review:

The influence of the lower electrode positions on the dynamic response of polysilicon MEMS resonators is the main study and presented in this literature. The change in the frequency response of investigated MEMS resonators as function of the lower electrode positions are measured using ANSYS software. The decrease in the amplitude if the lower electrode is moved from the beam free-end toward to the beam anchor is experimental monitored. The measurements are performed in ambient conditions. Different responses of MEMS resonators may be obtained if the position of the lower electrode is modified. Indeed the resonator stiffness and amplitude of oscillations are changed.

There are more studies in these areas;here is explain six papers in the same areas,the first paper is: Effects of the Electrode Positions on the Dynamical Behavior of Electrostatic-ally Actuated MEMS Resonators:This is the main paper that was built most of my studies upon it:The resonant frequency of a cantilever increases if the position of the electrode is moved from the beam free-end toward to the beam anchor but the velocity and amplitude of oscillations are decreasing respectively,The experiments were developed for cantilevers with two different widths,Experimental is demonstrated that, the quality factor of cantilever is decreasing and the damping ratio increases if the electrode is approached to the beam anchor.The second paper is: Nonlinear Dynamic Analysis of Electrostatic-ally Actuated Resonant MEMS Sensors Under Parametric Excitation:Nonlinear responses and dynamics of the electrostatic-ally actuated MEMS resonant sensors under two-frequency parametric and external excitations are presented, The responses of the system at steady-state conditions and their stability are investigated using the method of multiple scales, Response and dynamics of the MEMS resonator to a combination resonance are studied, Spring softening of the MEM structure shifts the resonant frequency to lower values, Resonant frequency shifting is a very important phenomenon, especially in resonant oscillators .The third paper is Pull-in Voltage Study of Micro-cantilever using ANSYS/Multiphysicsand COMSOL/Multiphysics:The present work involves the study of the pull-in voltage of a MEMS electrostatic cantilever, The voltage-electrode position dependence can be easily measured and are helpful for design decision making on the early design stages of this type of structures, Cantilever with appropriate modification can be made as switch, wherein electrodes and contact pads can be added .The fourth paper is: Dynamic response of an electrostatic-ally actuated micro-beam to drop- table test:The model accounts for the electrostatic bias on the micro-beam and the shock pulse of the drop-table test, the analytical simulation results are validated by finite-element results for the static response;a micro-machined cantilever beam made of gold of length 50 µm is subjected to drop-table tests while being biased by electrostatic loads.The fifth paper is: Nonlinear dynamics of an electrically actuated imperfect micro-beam resonator experimental investigation and reduced-order modeling:We present a study of the dynamic behavior of a micro-electromechanical systems (MEMS) device consisting of an imperfect clamped–clamped micro-beam subjected to electrostatic and electrodynamics actuation.The last paper is: Design of a tunable terahertz narrowband meta-material absorber based on an electrostatic-ally actuated MEMS cantilever and split ring resonator array:A dynamically tunable terahertz (THz) narrowband meta-material absorber is presented. The absorber is based on an electrostatic-ally actuated micro-electro-mechanical systems (MEMS) cantilever and split ring resonator (SRR) array, An equivalent LC circuit model for a transverse electric (TE) polarization wave is introduced to analyze the mechanism of frequency tuning, As it is actuated electrostatic-ally and can be fabricated by a MEMS surface micromachining process, this tunable meta-material absorber has good compatibility with integrated circuit technology.

1.3.1. Materials& Methods:

The resonator considered here is a resonant micro-cantilever formed from polysilicon under electrostatic actuation with different positions of the lower electrode as shown in Figure (1.1): the lower electrode at the beam free-end figure (b) and the lower electrode close to the beam anchor figure (c). The position of the lower electrode from the beam anchor is defined by the distance (*l-li*).

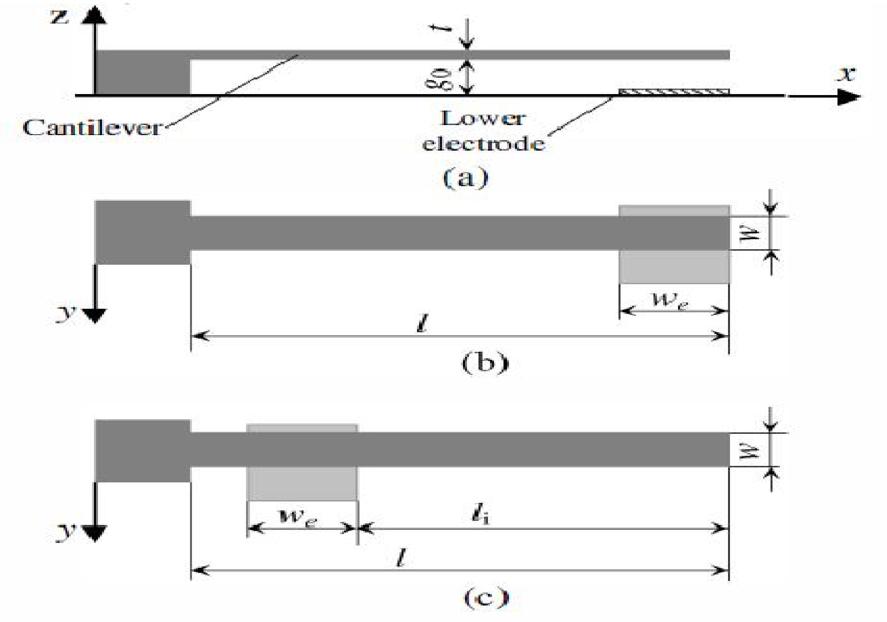

Figure (1.1): the lower electrode at the beam free-end (b).

: The lower electrode close to the beam anchor (c) [11].

When a DC voltage (VDC) is applied between electrode and the cantilever, an electrostatic force is set up and the cantilever bends downwards and come to rest in a new position. To drive the resonator at resonance, such as in mass sensing applications, an AC harmonic load of amplitude VAC vibrates the cantilever at the new deflected position.

A single degree of freedom model is used to simulate the dynamic response of the resonator due to the VDC and VAC electric loadings as presented in Figure (1.2):

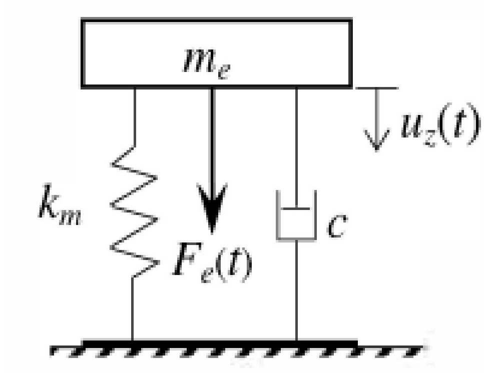

Figure (1.2): A single degree of freedom model[11].

In this model the proof mass of the cantilever is modeled as a lumped mass (me), and its stiffness is considered as a spring constant (km) depending on the position of the applied force. This part forms one side of a variable capacitor, the movable part. The bottom electrode is fixed and considered as the second part of the sensor. If an voltage composed DC and AC terms as:[11].

V(t)=VDC+VACcos(wt)Eq. (1.1)

is applied between resonator electrodes, the electrostatic force applied on the structure has a DC component as well as a harmonic component with the frequency w such as:[11].

$$F_e(t) = \frac{\varepsilon A\, V(t)^2}{2[g_0 - u_{z(t)}]^2} \quad \text{Eq. (1.2)}$$

Where (ε) ; is the permittivity of the free space, A=we×w is the effective area of the capacitor, (g_0) is the initial gap between flexible plate and substrate, and uz (t) is the Displacement of the mobile plate at x=(L-Li;) where the electrostatic force Fe(t) is applied. When only a DC voltage is applied across the plates (VAC = 0), and the lower electrode is positioned at the beam free-end, the static force balance equation, including the electrostatic force and the spring force is:[11].

$$k_m u_z - \frac{\varepsilon A\, VDC^2}{2[g_{0-}u_{z(t)}]^2} = 0 \quad \text{Eq. (1.3)}$$

Where (Uz) is the static displacement of the extremity of the beam under a DC signal.

In order, to estimate the effect of the lower electrode positions on the dynamic behavior of electrostatically actuated cantilevers, only the changes in the first bending mode of vibrations were monitored and analyzed.

During experimental tests a DC offset signal of 5V and peak amplitude of 5V of the driving signal are applied to bend and oscillate the samples. The frequency Response, the amplitude is measured of the investigated cantilevers. The change in the frequency responses of cantilevers as function of the lower electrode position is experimental determined. The tests are performed under ambient conditions.

1.3.2.Conclusions:

The resonant frequency of a cantilever increases if the position of the electrode is moved from the beam free-end toward to the beam anchor but the velocity and amplitude of oscillations are decreasing respectively.

1.4. Research Methodology:

The resonator considered here is a resonant micro-cantilever under electrostatic actuation with different positions of the upper electrode and different applied voltage, the upper electrode change it position starting from 100% of cantilever covered with upper electrode pad (starting from fixed part, and leaving gradually (by 10%) the tip of the cantilever without upper electrode) until 10% of cantilever covered with upper electrode pad.

When a DC voltage (VDC) is applied to the upper electrode an electrostatic force is set up and the cantilever bends downwards and come to rest in a new position**.**

In order, to estimate the effect of the upper electrode positions on the dynamic behavior of electrostatic-ally actuated cantilevers, the changes in the positions of the upper electrode and applied voltage will be monitor and analyze. The input voltage signal is different for all samples: start from 10mV to 200mV for every position of the upper electrode. The experiments were repeated 200 times for all samples, and the critical point for applied voltage is determined for every position of the Electrode pad in which the amplitude of deflection of the cantilever reach the total gap=3µm ,the results will be present and discuses.