

Sudan University of Science and Technology  
College of Engineering  
School of Mechanical Engineering – Department of Production  
Engineering

A Thesis submitted for the Honor Degree of BACHELOR of  
Mechanical Engineering

Title:  
EFFECT of COATING on RESIDUAL STRESSES in  
ELCTROSTATIC ACTUATOR  
MEMS DEVICE

Prepared by:

- 1- Amro Saif aldeen Mohamed Badry.
- 2- Omer Mohamed Altayib Ahmed.
- 3- Mohamed Hayder Hamed Ibrahim.

Supervised by:  
Dr.Musaab Abdallah Hassan Zaroug.

August 2014

## **Abstract:**

Constitute the pressures or stresses remaining one problems resulting from manufacturing may affect these stresses negatively on the performance of manufactured parts. These residual stress may be negative or positive, which is often generated as a result of the pains Due to difference in dimensions and the material distribution in the internal structure

. one of the methods used to get rid of this stress is textured paint on the manufactured workpiece

The important results in 0.01  $\mu\text{pa}$  pressure applied on the workpiece which changed the frequency from 1209.5  $\mu\text{hz}$  (natural frequency) to 3011.7  $\mu\text{hz}$  , with A layer (thickness = 2.2194465 $\mu\text{m}$ ) was added to the workpiece, the residual stresses were absorbed and the frequency reduced to 1208.5  $\mu\text{hz}$ .

## ملخص الدارسة:

تشكل الضغوط او الاجهادات المتبقية احد الاشكالات الناتجة من عملية التصنيع وتؤثر هذه الاجهادات سلبا على اداء القطعة المصنعة . وهذه الضغوط المتبقية قد تكون سالبة أو موجبة والتي غالبا ما تتولد نتيجة لمشاكل في التصنيع نسبة اختلاف في ابعاد القطعة وتوزيع المادة في البنية الداخلية . أحد الطرق المتبعة للتخلص من هذه الاجهادات هو اضافة طبقة للقطعة المصنعة. أهم النتائج التي توصلنا اليها باضافة ضغط . 10 ميكروباسكال على القطعة المصنعة تغير التردد من قيمة 0.1021 ميكروهيرتز ( التردد الطبيعي ) الى قيمة 710023 ميكروهيرتز وباضافة طبقة طلاء بسمك . 2.0022.1 ميكرومتر قلت قيمة التردد الي قيمة 0.1021 ميكروهيرتز.

# Contents

|                                                           |      |
|-----------------------------------------------------------|------|
| Title.....                                                | page |
| .....الاستهلال                                            | II   |
| Dedication.....                                           | III  |
| Acknowledgement.....                                      | IV   |
| Abstract.....                                             | V    |
| .....ملخص                                                 | VI   |
| List of Figures.....                                      | IX   |
| List of Tables.....                                       | X    |
| List of Abbreviations.....                                | XI   |
| Chapter One: (Introduction)                               |      |
| 1.1 Introduction .....                                    | 2    |
| 1.2 research problem.....                                 | 2    |
| 1.3 Objectives.....                                       | 2    |
| Chapter Two : (Theoretical background& Literature review) |      |
| 2.1 Introduction to MEMS.....                             | 4    |
| 2.2 Applications of MEMS.....                             | 4    |
| 2.3 Effects of pressure .....                             | 4    |
| 2.4 silicon .....                                         | 5    |
| silicon .....                                             | 5    |
| 2.4.1 why                                                 |      |
| 2.5 Actuator .....                                        | 6    |
| 2.5.1 Electrostatic actuators.....                        | 6    |
| 2.6 Finite element method (FEM).....                      | 6    |
| VIII                                                      |      |
| 2.7 ANSY.....                                             | 7    |
| 2.8 coating process .....                                 | 7    |
| 2.8.1 Effect of metal coating.....                        | 8    |
| 2.8.2 Conclusions.....                                    | 10   |
| Chapter Three : (Actuator design)                         |      |
| 3.1 Introduction.....                                     | 12   |
| 3.1.1 Base layer.....                                     | 12   |
| 3.1.2 Pad layer.....                                      | 12   |
| 3.2 The programming.....                                  | 12   |
| 3.2.1 Pre process.....                                    | 12   |
| 3.2.1.1 Element type.....                                 | 12   |
| 3.2.1.2 Material properties defining.....                 | 13   |
| 3.2.1.3 Geometry.....                                     | 13   |
| 3.2.1.4Mesh.....                                          | 14   |
| 3.2.1.5 Load definition.....                              | 15   |
| 3.2.2 Process.....                                        | 16   |

|                                                 |    |
|-------------------------------------------------|----|
| 3.2.3 Post process.....                         | 16 |
| 3.3 The flow chart.....                         | 17 |
| 3.4 Model validation.....                       | 18 |
| Chapter Four (Results review and analysis)      |    |
| 4.1 Introduction.....                           | 20 |
| 4.2 The frequency under pressure effect..t..... | 20 |
| 4.3 Conclusions.....                            | 30 |
| Chapter Five : (Conclusion& Recommendation)     |    |
| 5.1 Conclusions .....                           | 32 |
| 5.2 Recommendations.....                        | 32 |
| 5.3 References.....                             | 33 |

## List of Figures:

|                                                                              |      |
|------------------------------------------------------------------------------|------|
| Figure.....                                                                  | page |
| Figure (2.1) : Polysilicon beam with gold coating. ... ..                    | 8    |
| Figure (3.1) : geometry drawn for model .....                                | 13   |
| Figure (3.2) : mesh of model.....                                            | 14   |
| Figure (3.3) : geometry & loads of model.....                                | 15   |
| Figure (3.4) : geometry & loads of model.....                                | 15   |
| Figure (3.5) : resonance frequency by ANSYS.....                             | 19   |
| Figure (4.1) : geometry & applied loads(0.01 $\mu$ pa) of model....          | 22   |
| Figure (4.2) : geometry & applied loads(0.01 $\mu$ pa) & layer of mod .....  | 23   |
| Figure (4.3) : geometry & applied loads(0.02 $\mu$ pa) of model.....         | 24   |
| Figure (4.4) : geometry & applied loads(0.02 $\mu$ pa) & layer of model....  | 25   |
| Figure (4.5) : geometry & applied (0.03 $\mu$ pa) of model.....              | 26   |
| Figure (4.6) : geometry & applied loads(0.03 $\mu$ pa) & layer of model..... | 27   |

x

## List of Tables

|                                                                         |      |
|-------------------------------------------------------------------------|------|
| Table name.....                                                         | Page |
| Table (2.1) : Frequency with & without coating.....                     | 9    |
| Table (2.2) : Comparison between analytical and experimental result.... | 9    |
| Table (3.1) : material properties.....                                  | 13   |
| Table (3.2) : natural frequency.....                                    | 19   |
| Table (4.1) : frequency under pressure effect without layer.....        | 28   |
| Table (4.2) : frequency under pressure effect without layer.....        | 29   |

# List of Abbreviations

MEMS Micro-Electro-Mechanical System

FEM Finite Element Method

ANSYS Analysis System

Natural frequency

Thickness

Length

Density

Elasticity modulus

## **1.1– Introduction:-**

To understand the methodology and processes used in this Thesis it is important to have background information on the MEMS electrostatic actuator. Many different aspects will be covered in this research. Each section will cover some facet of the multidisciplinary technology of coating process . which can be considered as a part of a broad category of workpiece treatment.

## **1.2 - Research Problem:-**

Constitute the pressures or stresses remaining one problems resulting from manufacturing may affect these stresses negatively on the performance of manufactured parts. These residual stress may be negative or positive, which is often generated as a result of the pains Due to difference in dimensions and the material distribution in the internal structure which arise when manufacturing.

## **1.3 - Objectives:-**

This work aimed to study the effect of coating on residual stress in a micro workpiece made of silicon.