A Minor Project Report on

Design and Numerical Simulation of MEMS Microheater for Gas Sensing Application

MINOR PROJECT I REPORT

Submitted by

SUBASH.P (927621BEC213)

SIVARAMAKRISHNAN.M (927621BEC201)

YASAR.S (927621BEC245)

VIGNESHWARAN.S (927621BEC240)

BACHELOR OF ENGINEERING

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M.KUMARASAMY COLLEGE OF ENGINEERING

(Autonomous)

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BONAFIDE CERTIFICATE

Certified that this project report "DESIGN AND NUMBERICAL SIMULATION OF MEMS MICROHEATER FOR GAS SENSING APPLICATION" is the bonafide work of"P.SUBASH(927621BEC213),M.SIVARAMAKRISHNAN(927621BEC201),S.YASAR(9 927621BEC245),S.VIGNESHWARAN(927621BEC240)" who carried out the project work under my supervision in the academic year 2022-2023.

SIGNATURE

Dr.S.PALANIVELLRAJAN, M.E., Ph.D.,

HEAD OF THE DEPARTMENT

Proffessor

Department of Electronics and

Communication Engineering,

M.Kumarasamy College of Engineering,

Thalavapalayam,

Karur-639113

SIGNATURE

Dr.K.KARTHIKEYAN, M.Tech., Ph.D.

SUPERVISOR

Assistant Proffessor

Centre of Excellence in PCB,

Department of Electronics and

Communication Engineering,

M.Kumarasamy College of Engineering,

Thalavapalayam, Karur-639113

This Minor project -I report has been submitted for the **18ECP103L Minor Project I** Review held at M.Kumarasamy College of Engineering, Karur on 2022 - 2023.

PROJECT COORDINATOR

Vision of the Institution

To emerge as a leader among the top institutions in the field of technical education

Mission of the Institution

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully engaged, learner-centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry, and Professional associations.

Vision of the Department

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research, and social responsibility.

Mission of the Department

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives (PEOs)

- **PEO1: Core Competence:** Graduates will have a successful career in academia or industry associate with Electronics and Communication Engineering.
- **PEO2: Professionalism:** Graduates will provide feasible solutions for the challenging problems throug comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.
- **PEO3: Lifelong Learning:** Graduates will contribute to the social needs lifelong learning, practicing professional ethics and leadership quality through

PROGRAM OUTCOMES (POs)

- **PO1: Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems
- **PO2: Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
- **PO3: Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
- **PO4: Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions
- **PO5: Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations
- **PO6: The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice

- **PO7: Environment and sustainability:**Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO8: Ethics :**Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice
- **PO9: Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings
- **PO10: Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions
- **PO11: Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments
- **PO12: Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

- **PSO1**: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.
- **PSO2**: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations**.**

MAPPING OF PROJECT WITH POs AND PSO

Abstract	**Matching with POs , PSOs**
Keywords	PO1,PO2,PO3,PO4,PO5,PO6,PO7,PO8, PO9,PO10,PO11,PO12. PSO1,PSO2.

ABSTRACT

Micro Electro Mechanical System (MEMS) technology has always been the most important part in the development of micro-heaters and thus, high-performance gas sensors. Micro-heaters have been widely used in gas sensors with high sensitivity. This paper provides the design and simulation of serpentine shape micro-heaters with interdigitated electrodes (IDE). We have studied different heater materials such as copper, nickel, silver, gold and platinum over the polycrystalline substrate for achiving low power consumption, uniform temperature distribution and long-term stability high mechanical strength. We have designed a MEMS microheater using COMSOL Multiphysics. Smart gas sensors are attracting considerable research interest as sensor devices that can contribute to the highly sensitive, low response time, multi-analyte detection, low cost, and highly reliable systems which can be used in industrial, military, indoor applications. The performance of the Smart gas sensor can be assessed in terms of the sensing material, structure, technique, and power consumed by the whole device. Likewise, the sensing capacities of the Smart gas sensor can be affected significantly by a selection of micro heaters used in it. Enormous efforts have thus been put in to make them more competitive with existing options for reducing the power of the whole circuit. In this work, a comparison of different microheaters in the nano regime is made and various parameters such as power consumption, and the uniform temperature distribution are calculated. The result obtained could direct a perfect way for the fabrication of devices and save money as well as time. This work will help for the fabrication of portable devices with a reduced power consumption of smart gas sensors.

Table of Contents

List of Figures

List of Tables

Acronyms/List of Abbreviations

S.No.	Acronyms	Abbreviations
1	MEMS	Micro Electro-mechanical system
2	COMSOL	Computer and solution
3	FEM	Finite Element Method
4	MHP	Micro Hotplate
5	CAD	Computer Aided Designing
6	AC	Alternate current
7	DC	Direct current

NOMENCLATURE

The nomenclature should contain list of symbols in alphabetical order with capital letters followed by lowercase letters, Greek alphabets in alphabetical order, superscripts and subscripts in that order in the following format. Units in SI system should be mentioned in bracket against each quantity. For dimensionless quantities, the word "dimensionless" should be written in place of unit.

A Area (m^2)

a Length of specimen (m)

D Diameter of rod (m)

Greek Symbols

a Volumefraction(dimensionless)

h Efficiency (dimensionless)

Superscripts

(n) nth iteration

Subscripts

a Air

1. INTRODUCTION

Micro Electromechanical System which is usually called MEMS. MEMS based gas sensors being miniaturized have various advantages such as low power consumption, robust and stable electric properties. These gas sensors have three main components interdigitated electrode and sensing film. Within the traditional MHP gas sensor, the heating electrodes and the test electrodes are not on the same plane. With such traditional design, the manufacturing process is complex, and the heat transfer is not very good, and a parasitic electric field is likely to take form among the heating layer, insulating layer and testing layer, exerting certain influences on the signal to be tested. In this new design, the heating electrode and the testing electrode are placed on the same plane.

In this paper the design and simulation of serpentine shape micro heaters were used for the analysis of uniform temperature distribution, power consumption because of its higher efficiency and higher operating temperature. Interdigitated electrodes are used because the reduced distance between the electrodes enable quicker ion diffusion leads to higher power density and performance. Micro heaters play a key role in controlling temperatures in lab-on- chip devices due to their ability to affect the temperature locally. Micro heaters based on Gold have excellent physical properties like gold can be able to reflect the heat rather than other materials. Gold can efficiently transfer heat and electricity. By analyzing the various properties like low power consumption, least volume change during heating, better temperature uniformity of different micro heater materials such as copper, silver, nickel, platinum. Gold gives better results when compared to others. Geometry, temperature and electric field norms are attached below.

1.1. Objectives

1. To provide the uniform heat distribution all around the micro heater.
2. To reduce the input supply voltage and improve the efficiency of micro heater.
3. To reduce the power consumption and bulkiness.
4. Fast thermal response.
5. Well controlled Temperature distribution.

2. DESIGN OF MEMS MICRO HEATER

2.1. Geometry of Device

The design of MEMS micro heater was designed using CAD tool.

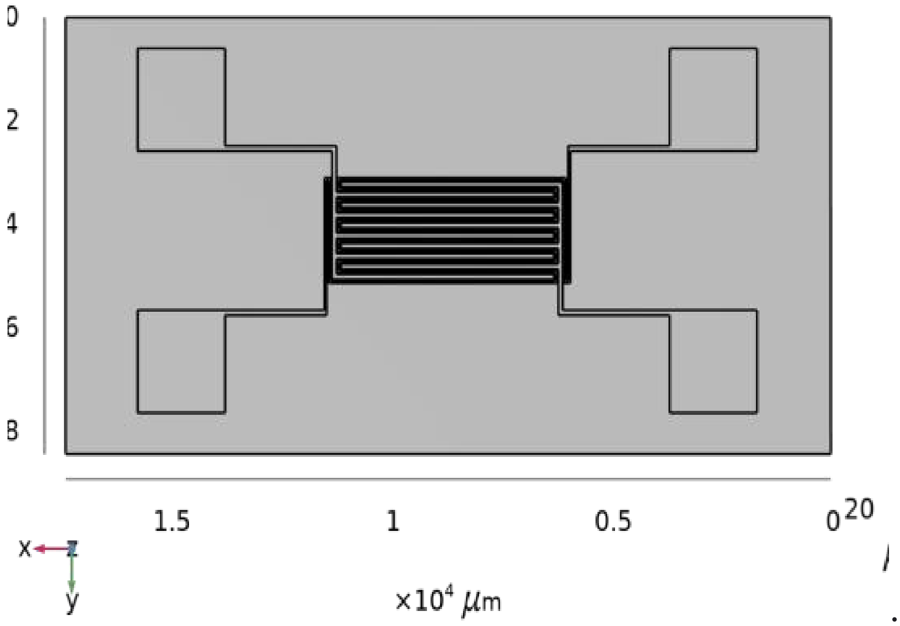

Figure 2.1 Geometrical design of micro heater

Figure 2.1 shows the geometrical design of the micro heater. The space between the two electrode is 50µm, width of the electrode is 100µm and thickness of the heater structure is 100 nm. Table 2.1 shows the geometry statistics of the device and Table 2.2 shows the material parameters for gold.

Table 2.1 Geometry statistics

Description	**Value**
Space dimensions	3
Number of boundaries	4
Number of Domains	164
Number of edges	468
Number of Vertices	312

Table 2.2 Material parameters for gold

Material properties	Value	Unit
Electrical conductivity	45.6e6	S/m
Coefficient of thermal expansion	14.2e-6[1/K]	1/K
Heat capacity at constant pressure	129[J/(kg*K)]	J/(kg·K)
Density	19300[kg/m^3]	kg/m^3
Thermal conductivity	317[W/(m*K)]	W/(m·K)
Relative permittivity	1	1
Relative permittivity	70e9[Pa]	pa
Poisson's ratio	0.44	1

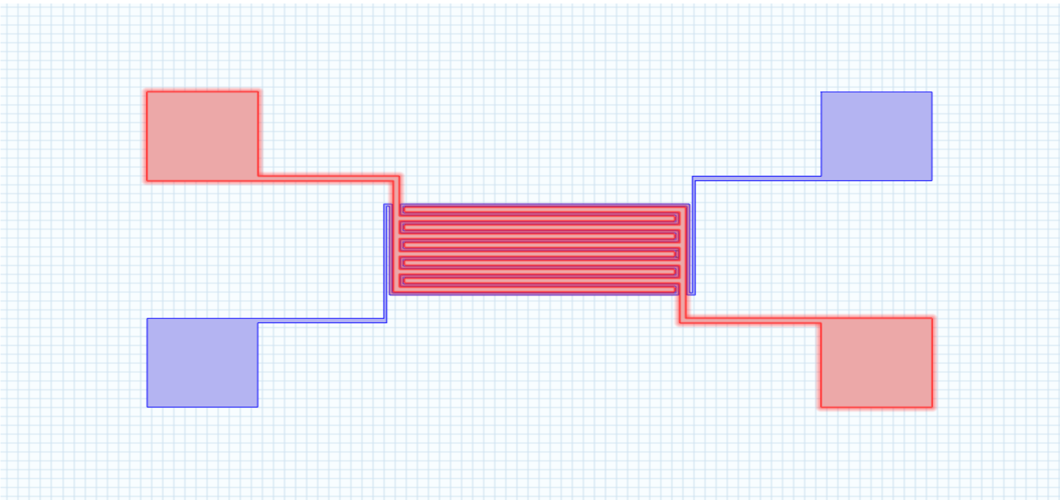

Figure 2.2 Over all device structure of micro heater with IDE

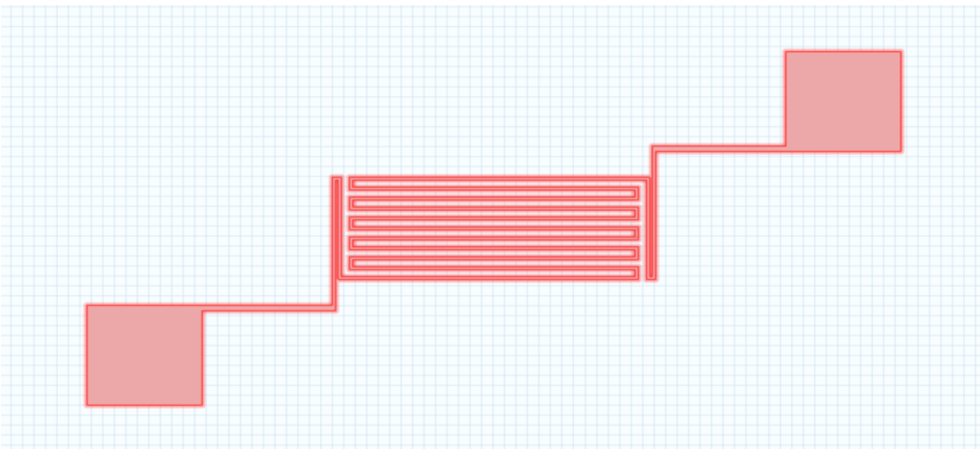

Figure 2.3 Geometrical design of micro heater

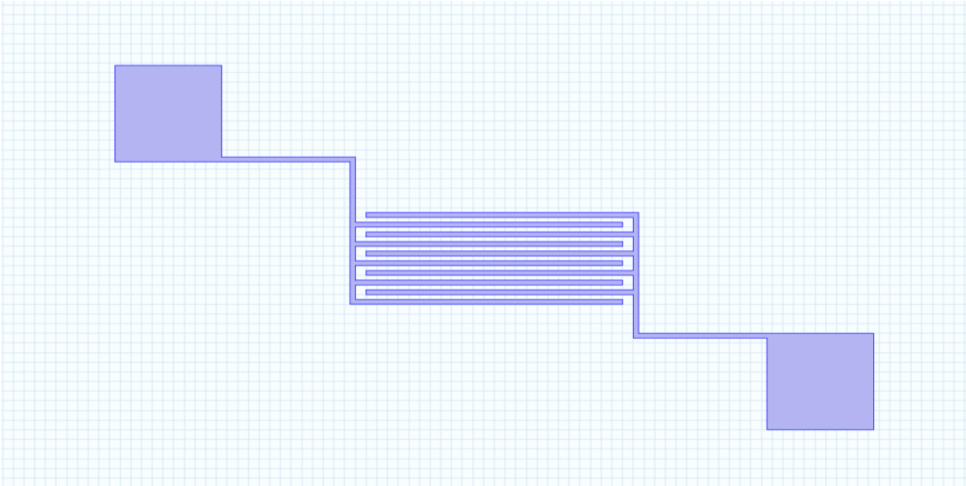

Figure 2.4 Geometrical design of IDE

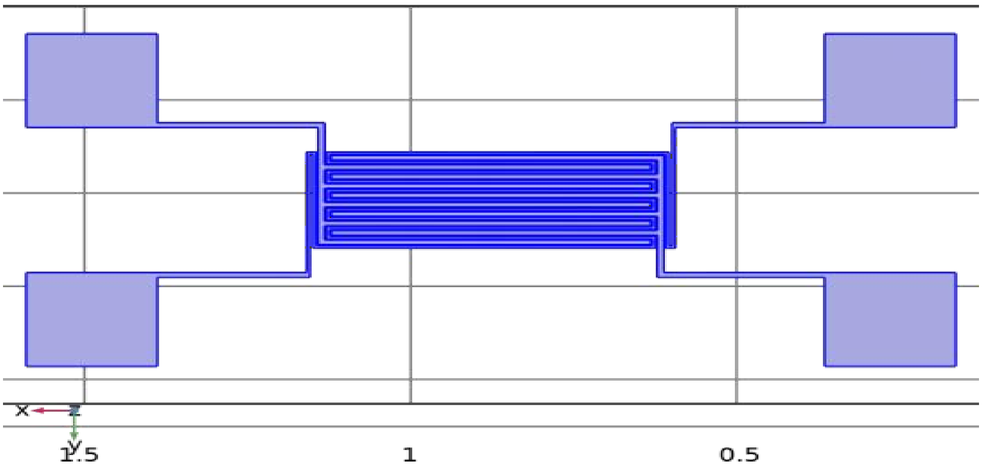

Figure 2.5 Geometrical design of gold micro heater

Figure 2.2 shows the Over all device structure of micro heater with IDE, Geometrical design of micro heater shows in figure 2.3 then figure 2.4 shows the geometrical design of IDE and geometrical design of gold micro heater shows in figure 2.5.

3. MATHEMATICAL MODELLING

3.1. Mathematical modelling

The Joule heating model node in COMSOL uses the fol- lowing version of the heat equation as the mathematical model for heat transfer in solids.

$$Q \propto |J|^2$$

Where, Q—Amount of heat in Joules; J—Current Density in (A/m^2).

The coefficient of proportionality is the electrical resistivity p 1/σ , which is also the reciprocal of the temperature dependent electrical conductivity σ σ(T).Combining these facts gives the fully coupled relation,

$$Q = \frac{1}{\sigma}|J|^2 = \frac{1}{\sigma}|\sigma E|^2 = \sigma|\nabla V|^2$$

Where, σ—Electrical Conductivity (in S/m); E—Electric field (in V/m).

Over a range of temperature, the electric conductivity σ is a function of temperature T.

$$\sigma = \frac{\sigma_0}{1+\alpha(T-T_0)}$$

Where σ_0 is the conductivity at the reference temperature T_0 and σ is the temperature coefficient of resisitivity, which describes how the resistivity varies with temperature.

Also the power consumption is calculated using the formula

$$P = V\,2/R$$

Where, V —applied voltage (in V);R—Resistance (in Ω).

Here power consumption is directly proportional to the applied voltage and inversely proportional to the resistance of the material. Table 3.1 shows the material properties used for micro fabrication.

The resistance of the heater can be calculated using the formula

$$R = pl/wt$$

Where, l—Length of the heater (in m);

w—Width of the heater (in m).

Table 3.1 Material properties used for micro fabrication

Name	**Silicon**	**Poly silicon**	**Titanium**	**Platinum**	**SiO**
Relative permittivity	11.7	4.5	100	$1.265e^{-6}$	4.2
Electrical conductivity	10	$5e^{4}$	$2.6e^{6}$	$8.9e^{6}$	$12e^{-5}$
Co-efficient of thermal expansion [1/K]	$2.6e^{-6}$	$2.6e^{-6}$	$8.60e^{-6}$	$8.80e^{-6}$	$0.5e^{-6}$
Heat capacity at constant [J/(kg K)]	700	678	522	133	730
Density [kg/^{3}]	2329	2320	4506	21450	2200
Thermal conductivity [W/(m K)]	130	34	21.9	71.6	1.4
Young’s modulus [Pa]	$170e^{9}$	$160e^{9}$	$115.7e^{9}$	$168e^{9}$	$70e^{9}$
Poisson’s ratio	0.28	0.22	0.321	0.38	0.17

4. ELECTRIC POTENTIAL

The figure 6.1 shows the electric potential distribution across the device. The top left corner of the device is weakest which is grounded and field strength at the middle is 0.5V and top left corner of the device is strong which is input voltage 0.25, 0.50, 0.75 and 1V.

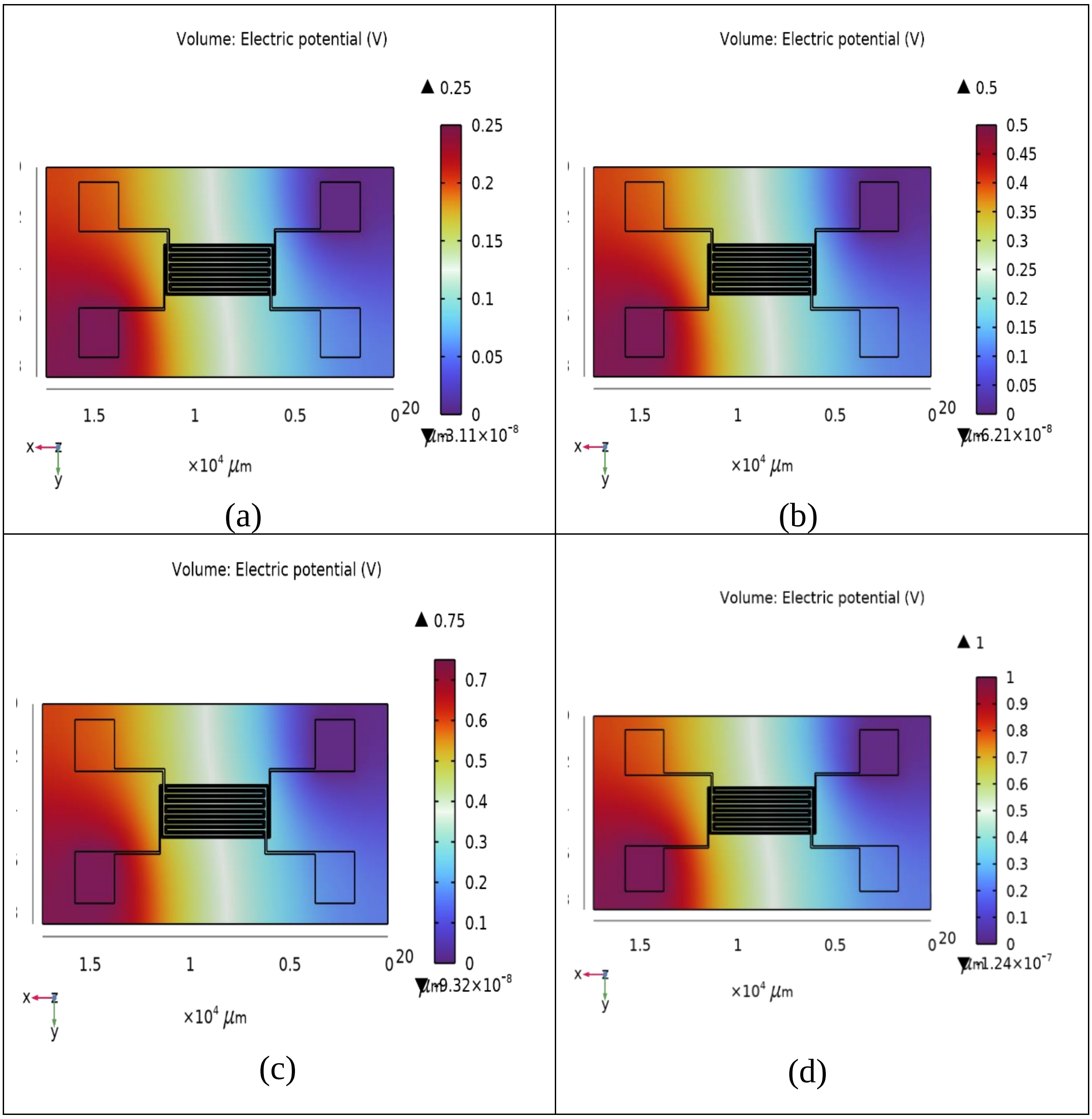

Figure 4.1 Electric potential distribution in micro-heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0 V

Table 4.1 Temperature obtained in different material

	Input Voltage				
S.No.	Materials	Input Voltage(0.25)	Input Voltage(0.50)	Input Voltage(0.75)	Input Voltage(1.0)
1	Pt	325k	421k	581k	837k
2	**Au**	**327k**	**429k**	**598k**	**839k**
3	Ag	326k	425k	595k	837k
4	Ni	325k	422k	584k	809k
5	W	325k	424k	585k	811k

Table 4.1 shows that the temperature obtained in various thin film materials such as Pt, Au, Ag, Ni and W. However using Pt as heater electrode, the tempetature level is increasing in the order of 0.25<0.50<0.75<1.0 Voltage. While using Ag as heater electrode, the tempetature level is growing in the order of 0.25<0.50<0.75<1.0 Voltage. While using Ni as heater electrode, the tempetature level is increasing in the order of 0.25<0.50<0.75<1.0 Voltage. While using Au as heater electrode, the tempetature level is increasing in the order of 0.25<0.50<0.75<1.0 Voltage. Reason for using gold as heater electrode is by its ambient nature and its does not oxide easily.

5. TEMPERATURE DISTRIBUTION

Figure 5.1 shows temperature distribution in gold micro heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0. We can find that the maximum heat level was obtained at the centre of the device and the temperature is uniformly distributed all over the device by which the material properties, device structure and low power consumption.

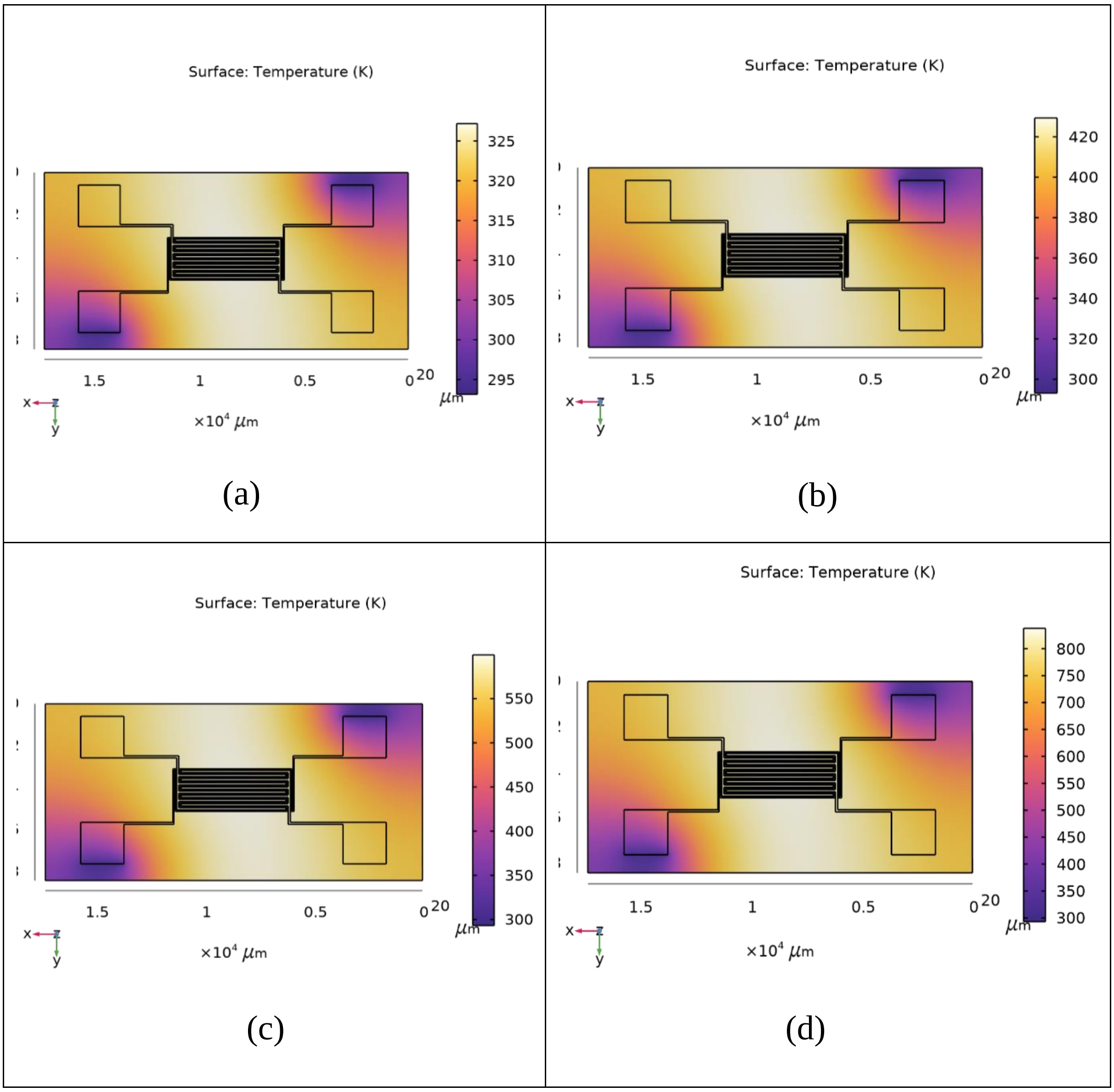

Figure 5.1. Temperature distribution in gold micro heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0

$$\rho = RA/L$$

where, ρ - Resistivity

R-Resistance of the specimen

A-area of cross section

L-length of the conductor

Where the resistivity of a material Is dependent on the length of the conductor.

6. ISOTHERMAL CONTOUR

Figure 6.1 shows the Isothermal contour plot with different voltages such as 0.25, 0.50, 0.75 and 1.0. Isotherms are lines connecting points of equal temperature. As a result, every point along a given isotherm has the same temperature value.

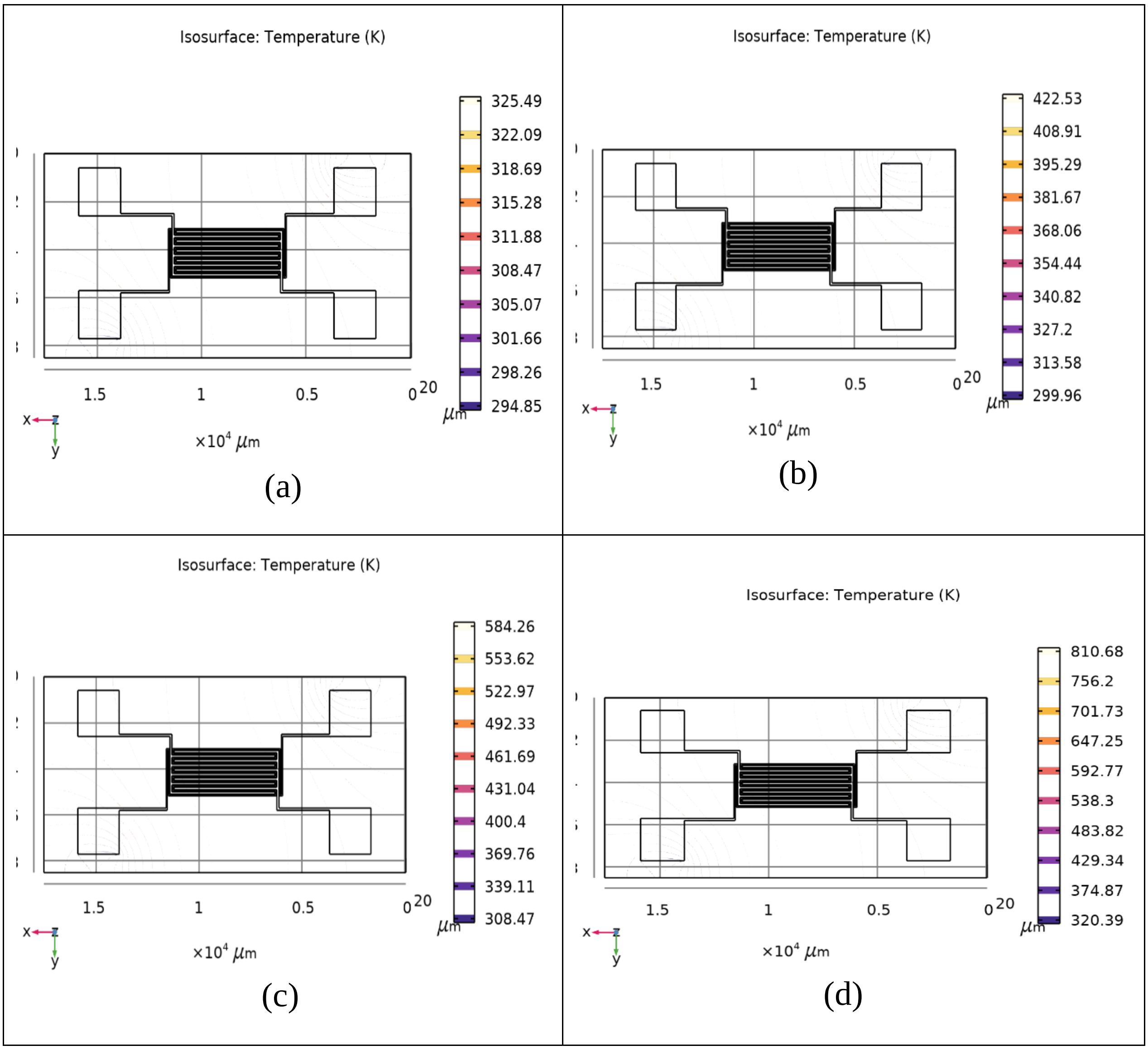

Figure 6.1 the Isothermal contour in the micro heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0

7. STRESS CONSIDERATION

Though the designed microheaters stress analysis should be performed on the non-supportive thin film structures i.e., flexures, to analyse whether such thin film structures can withstand the forces applied on them due to increasing the temperature and not become fragile after fabrication.

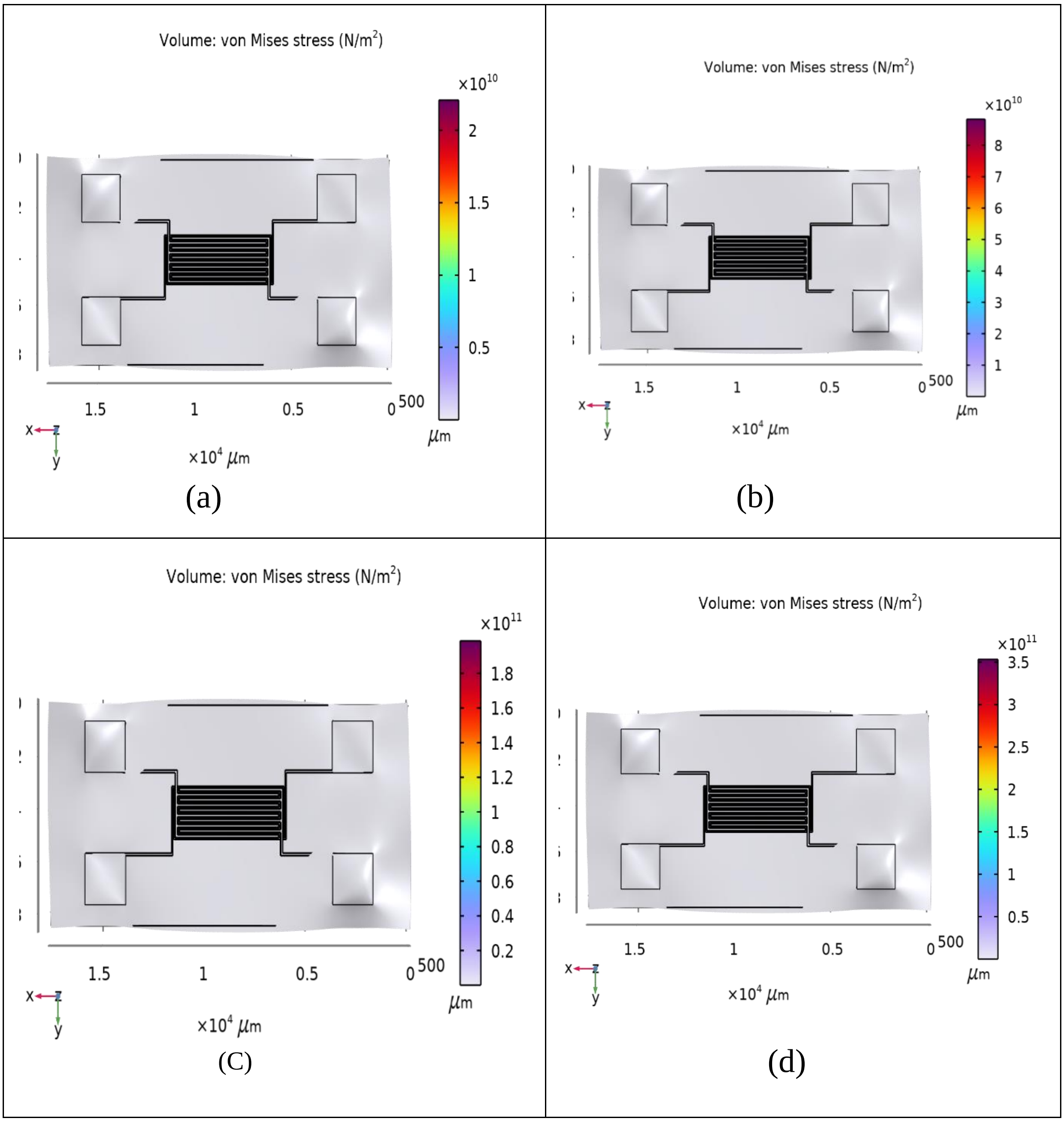

Figure 7.1 Stress in the micro-heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0

The stress can be calculated by using the formula:

$$E = \sigma/s$$

Where, E—Young's Modulus (Pa);

σ—Stress (Force applied per unit area;N/m^2 or Pa);

s—Strain (Change in length, owing to the force applied across original length- dimensionless).

The Equation, has been solved under Neumann. The boundary conditions are applied using Finite Element method (FEM) when the electro-thermal module selected in COMSOL. Figure 7.1 shows the stress at overall substrate and its very low but stress at the electrode is very high which means the electrode can withstand a huge external force

8.ELECTRIC FIELD NORM(ec)

Here norm means the amplitude of the electric field:

normE = sqrt($Ex^2 + Ey^2 + Ez^2$)

This is the norm of E field matrix

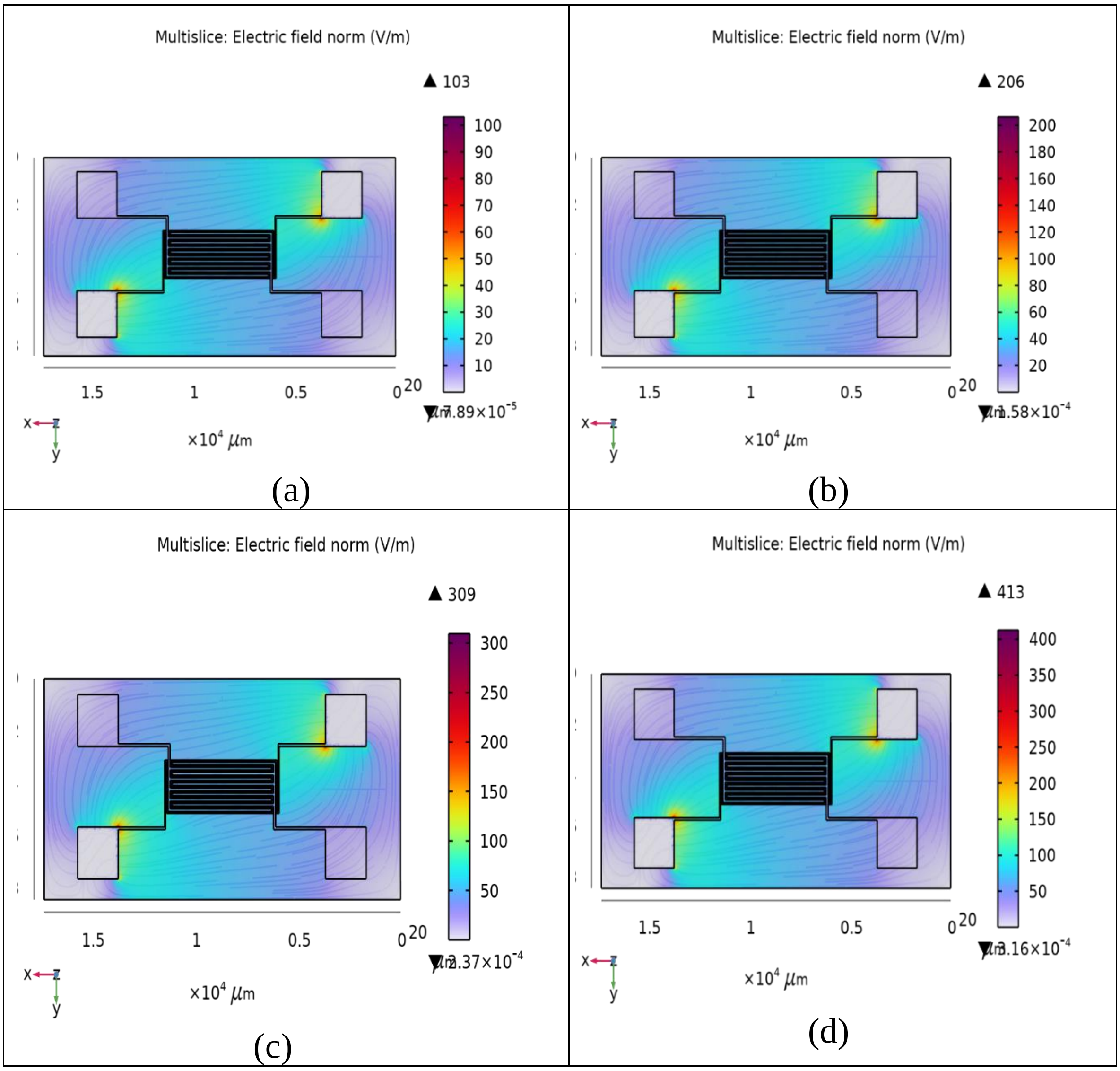

Figure 8.1 Electric field norm in the Micro-heater at different voltages (a) 0.25, (b) 0.50, (c) 0.75 and (d) 1.0 V.

9.REASON FOR USING GOLD

1. Ambient Nature of Gold.
2. Have bettter uniformity.
3. Good specific heat capacity.
4. Does not Oxide easily.

- **Lifetime and reusability:** Materials such as SiO_2 should be deposited above the heater to minimize the oxidation of the heating element via encapsulating the entire structure from the environment, which elevates the long-term reliability and reusability of the device.

- **Uniform heating:** The heater should produce identical heating all over the active area and no hotspots. The design plays a crucial role in managing the thermal distribution by varying the resistance. The high thermal conductive layer above the heater influences better thermal distribution in the gaps of the heater filament.

- **Mechanical stability:** The substrate should be capable of working at ambient temperature and withstand maximum temperature for desired applications. The decrease in stress and displacement will improve the mechanical strength of the microheater. The deformation gradient and thermal expansion of the microheater must also be lower to achieve efficient results. Nevertheless, the microheater material and its structure influence the stability.

- **Response time:** The short response time drastically reduces the time requirement and the power consumption. Several temperature control systems and algorithms are available to integrate with the microheater.

- **Power consumption:** The optimal design, thickness, substrate, and thermal conductive layer influence better power consumption. The cavity in the insulating substrate can also improve power consumption effectively. In addition, the increase in resistance declines the overall power usage, which enhances battery-operated devices for portability and easy

10. MEMS MODULE

Engineers and scientists use the MEMS Module to understand, predict, and design microsystemsThrough the use of simulation tools in the design cycle, understanding can be enhanced, prototyping can be reduced, and in the end, better products can be produced at a lower cost. Using the MEMS Module, users can predict the structural, electrical, and thermal performance of MEMS devices quickly and accurately. In addition to the multiphysics capabilities built into COMSOL Multiphysics, the software is particularly suitable for addressing a wide range of problems encountered in the design of MEMS devices. With the MEMS Module, the stationary and dynamic performance of devices can be modeled in two and three dimensions as well as circuit-based models of active and passive devices.

There are powerful tools available for modeling devices driven by a combination of AC and DC signalsA wide range of physical phenomena can be addressed with predefined physics interfaces, commonly referred to as MEMS physics interfaces.MEMS physics interfaces are available for simulating structural mechanics, electrostatics, electric currents, piezoelectricity, piezoresistivity, thin-film fluid flow, heat transfer, and electrical circuits. These physics interfaces can also be coupled together arbitrarily to solve multiphysics problems, and a number of predefined couplings are also available as MEMS physics interfaces. These include electromechanics (for combining electrostatic forces with structural mechanics), Joule heating, Joule heating and thermal expansion, and fluid-structure interaction (for combining fluid flow with structural mechanics). For each of the MEMS physics interfaces, the underlying physical principles are expressed in the form of partial differential equations, together with corresponding initial and boundary conditions. COMSOL's design emphasizes the physics by providing users with the equations solved by each feature and offering the user full access to the underlying equation system. There is also tremendous flexibility to add user-defined equations and expressions to the system. For example, to model Joule heating in a structure with temperature-dependent elastic properties simply enter in the elastic constants as a function of temperature no scripting or coding is required. When COMSOL compiles the equations the complex couplings generated by these user-defined expressions are automatically included in the equation system. The equations are then solved using the finite element method and a range of industrial strength solvers. Once a solution is obtained a vast range of postprocessing tools are available to analyze the data, and predefined plots are automatically generated to show the device response.

COMSOL offers the flexibility to evaluate and visualize a wide range of physical quantities including predefined quantities such as the 6 | temperature, the electric field, or the stress tensor (available through easy-to-use menus), as well as arbitrary user-defined expressions. Then appropriate materials are selected and a suitable MEMS physics interface is added. Initial conditions and boundary conditions are set up within the physics interface. Next, the mesh is defined and a solver is selected. Finally the results are visualized using a wide range of postprocessing tools. All of these steps are accessed from the COMSOL Desktop graphical user interface

11. CONCLUSION

Test and Simulation were done for the Parallel plate Microheater, and various temperature obtained for applying five different voltages to different heating elements like platinum, copper,nickel,silver. And the suitable heating element(gold) was selected as the best among the other.in future after the fabrication of this micro heater it can be subjected to the extensive applications like gas sensors, humidity sensors, and others. And by analyzing the micro heater design using MEMS based COMSOL software we have found that gold has low thermal mass and better temperature uniformity.

Microheaters find their application in various fields, such as science, engineering, mining, and space. This review summarizes the technological developments in designing and fabricating a microheater for general and specific applications. Though there are multiple technologies available, the study had focused on providing an overview of knowledge and considerations for manufacturing microheaters.

Additionally, the importance of selecting suitable heating elements is briefly explained so that future researchers can look up to this article for a glimpse of information. Moreover, we furnished the details about computational modeling and designing in suitable simulation software to arrive at the best heating element design for practical applications. It is witnessed that most of the research and development has been focused on metal microheaters through which significant improvements were made to develop an optimized microheater. This review will be a valuable reference for the researchers who work and needs further knowledge in the field of microheaters. Further, computational modeling should be performed for the analysis of various microheater designs that will be crucial for predicting and enhancing the thermal uniformity for specific applications. Moreover, the development of reusable and low-cost microheaters using inexpensive substrates and heater materials will be considered as future work.Finally, specific research should be implemented to expand the application of paper-based microheaters for disposable low-temperature microdevices to circumvent cross-contamination and biohazard.

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Dharapuram Road,Avinashipalayam,

Tirupur - 638 660

&

BARANI HYDRAULICS INDIA PRIVATE LTD

mail id : rime2k21@gmail.com

website : www.jayshriram.edu.in

DESIGN AND NUMERICAL SIMULATION OF MEMS MICROHEATER FOR GAS SENSING APPLICATION

K.Karthikeyan[1*], P.Subash[2], M.Sivaramakrishnan[3], S.Vigneshwaran[4] and S.Yasar[5]
Centre of Excellence in PCB[1],UG Scholar[2,3,4,5]
Department of Electronics and Communication Engineering
M.Kumarasamy College of Engineering, Karur, Tamil Nadu, India

ABSTRACT

Micro Electro Mechanical System (MEMS) technology has always been the most important part in the development of micro-heaters and thus, high-performance gas sensors. Micro-heaters have been widely used in gas sensors with high sensitivity. This paper provides the design and simulation of serpentine shape micro-heaters with interdigitated electrodes (IDE). We have studied different heater materials such as copper, nickel, silver, gold and platinum over the polycrystalline substrate for achieving low power consumption, uniform temperature distribution and long-term stability high mechanical strength.

Keywords: MEMS, IDE, Heater Materials

ABOUT THE INSTITUTION

JAI SHRIRAM
ENGINEERING COLLEGE

Jai Shriram Engineering College was endowed by Shenthil Velevan Trust in the year 2009 with a motto of equipping and implanting the seed of higher education blended with communal harmony to the rural community in and around the Textile City. JSREC reinforces to impart knowledge, teamwork innovation,entrepreneurship, courage, sacrifice and duty which are innards of a meaningful life. Here we look at education as a complete experience. Not just as academics and it laid a pavement for JSREC to a world-class education environed with an eco-friendly greenery rich campus life.

JSREC is also promoted by leading industrialist having 3 major manufacturing divisions in Coimbatore with international reputation and hence we stand forth in creating great minds with optimal advantage in terms of advanced technical knowledge and skills in the distinct aspects of intellectual growth and development JSREC is renowned for its Industry Academic Interaction.

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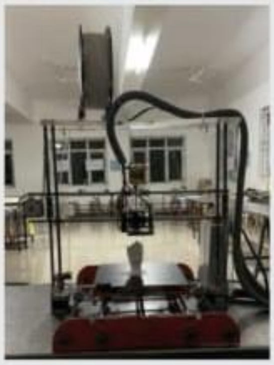
ABOUT THE DEPARTMENT

The department was started in the year 2009 for the undergraduate program in B.E. Mechanical Engineering with an intake of 60 students. The department offers high quality education to the students through very good infrastructure, laboratories, and faculty and by means of exposure to latest technologies.

The department has highly qualified and well experienced teaching staff, who take extreme care for the development of the careers of the students. The department is very much oriented towards research and development as well as in consultancy.



ABOUT THE CONFERENCE

Jai Shriram Engineering College, Tiruppur is one of a pioneer in the field of Technical Education happy to declare its National Conference on Recent innovations in Mechanical Engineering (RIME2'k22) on November 18, 2022 sa platform for intellectuals from anousuniversibes, research institutes, terprises and experts across the globe to gather and exchange their ideas and findings of recent developments in Mechanical Engineering This conference is also promulgated through presentations basic expeditions applcations and case studies in the broad area of Mechanical Engineering.

RIME 2k22 acts as a forum for the academic as well as industrial community to address the opportunities & challenges and to discuss the scope for future research The conference will bring together academicians research scholars, engineers and scientists to exchange and share their expertise. The conference will provide an opportunity for the presentation of new advances in theoretical and experimental research in the fields of Mechanical Engineering. It will also focus on emerging fields Like Energy, Robotics, Mechatronics, Automation, CAD/CAM, Composite Materials, Green Manufacturing and Nanotechnology. These are expected to create new job opportunities for Mechanical engineers in our country.

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Department of Mechanical Engineering

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CERTIFICATE OF PARTICIPATION

This Certificate is awarded to ~~Dr~~ /Mr /~~Ms~~ ....SIVARAMA KRISHNAN.....M................of ...M. KUMARASAMY.....COLLEGE....OF.....ENGINEERING.........................for presenting a paper entitled ...DESIGN...AND...NUMERICA...SIMULATING...OF...MEMS...MICROHEATER...FOR...GAS...SENSING...APPLICATION... in 2nd **National Conference on Recent Innovations in Mechanical Engineering (RIME'2K22)** Organized by the Department of Mechanical Engineering on 18th November 2022.

Prof.S.Karthikeyan Prof.P.Rajkumar	Dr.R.J.Golden Renjith Nimal	Dr.C.Rameshkumar
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