CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Presently, the micro tubular coil heater wires are manufactured using Nickel-Chrome alloys, which are resistant to high temperatures. A relatively low temperature coefficient of resistance with a high resistivity makes it suitable for control resistors and heating element for tubular heaters. Due to the increase in resistivity with the reduction in cross sectional area, its operating temperature is limited to 900 ºC, which is very low for most of the heating applications. In order to use micro tubular coil heaters more than 900 ºC, a new material is to be identified which is stable even at high temperatures.

A detailed literature survey has been made on the following areas.

- Possible micro tubular coil heater materials which are suitable for high temperature applications
- Application of Raman spectroscopy to determine the thermal stability of the materials
- Finite element simulation of different heater materials
- Experiments to find the temperature pattern for different electrical inputs, and validate the finite element simulation results.
2.2 SELECTION OF MATERIALS FOR MICRO TUBULAR COIL HEATERS

Brafman et al (1968) studied the Raman spectra of Wurtzite AlN and Zincblende BN and BP, which were excited by a He-Ne laser and the long wavelength Raman lines were determined and analyzed.

Singh et al (1972) studied the electrical resistivity and resistance - temperature characteristics of Titanium films were measured in vacuum. They varied the thickness of the film and studied the Temperature Coefficient of Resistance and electrical resistivity.

Akio Kato and Nobuyuki Tamari (1975) presented a detailed study on Titanium Nitride and investigated the crystal growth of Titanium Nitride, by conducting an experiment using chemical vapour deposition. They observed the needle crystals grew in the region of the substrate, whose temperature was at 1200 °C to 1300 °C, they had diameters of 5-140 μm. The growth rate of needle crystals showed maxima against Titanium Tetrachloride and Nitrogen concentrations.

Glen A. Slack and McNelly (1976) reviewed the problems associated with the growth of high purity crystals of AlN. They described a new technique for producing high purity AlN powder from Al metal, by use of AlF₃ as an intermediate product and they found that the AlN powder can be converted into single crystals by sublimation in a closed tungsten crucible or in an open tube with a gas flow.

Yasuhiro Igasaki et al (1978) performed an experiment by evaporating metallic Titanium on glass substrates, heated at temperature between 300°C to 500°C to study the structure and electrical properties of Titanium Nitride Films. X-ray analysis revealed that the films were composed
of $\alpha$-Titanium, distorted Titanium phase, amorphous phase, and TiN. The excess resistivity of the distorted Titanium phase can be mainly interpreted in terms of two kinds of carrier scattering, one due to nitrogen atoms randomly distributed at vacant interstitials, and another attributable to grain boundaries involved.

Wittmer et al (1981) investigated the oxidation kinetics of TiN thin films in dry O$_2$ in view of a possible application of TiN as material for gate electrodes and interconnections in large scale integrated circuits. They found that, in the temperature range of 500 to 650°C the oxidation is thermally activated with an activation energy of 2.05±0.05 eV.

Suni et al (1983) studied behaviour of dry and wet oxidation on TiN and HfN and found that the dry oxidation in TiN is much faster than the dry oxidation of HfN at a given temperature and the oxidation rate was always higher in a wet than in a dry ambient.

Abid et al (1986) investigated the thermal stability of AlN powders and thin films using Reflection High-Energy Electron Diffraction (RHEED) and X-ray diffraction. They found that AlN was stable up to 1000°C in air and remains stable up to 1400°C and it did not oxidize up to these temperatures.

Dinwiddie et al (1989) investigated the thermal transport properties of four commercially available AlN substrates using a combination of steady-state and transient techniques. Low-temperature measurements of thermal conductivity and heat capacity were used to probe the mechanisms that limit the thermal conductivity in AlN.
Yokoyama et al (1991) investigated the characteristics of TiN films formed by Low-Pressure Chemical Vapour Deposition (LPCVD) for application to the barrier layers in Ultra-Large-Scale Integration (ULSI).

Yoshiyuki Yasutomi et al (1991) studied the development of reaction-bonded electroconductive Silicon Nitride - Titanium Nitride and Resistive Silicon Nitride - Aluminum Oxide composites reaction-bonded Si$_3$N$_4$. They found that complex ceramics was attributed to the small dimensional change at the nitriding stage, under 0.3%.

Watari et al (1992) produced extremely large grain size AIN ceramics by HIP sintering at an ultra-high temperature of 2773 K without reducing the oxygen content, in order to determine experimentally, whether the factor controlling thermal conductivity is either grain boundaries or the internal structure of the grains. They examined that the thermal conductivity of sintered AIN is controlled by the internal structure of the grains, such as oxygen solute atoms.

Hiroshi Ichimura and Atsuo Kawana (1993) analyzed the high-temperature oxidation of TiN, Ti$_{0.9}$Al$_{0.1}$N, and Ti$_{0.6}$Al$_{0.4}$N films which were deposited onto stainless steel substrates using an arc ion-plating apparatus at temperatures ranging from 923 K to 1173 K. The oxidation rate was decreased with the increasing Al contents and the activation energies of oxidation reaction increased. The oxide layers, which formed, were analyzed by XRD, SEM, and EPMA. The rate-determining step changes from oxygen ion diffusion in formed rutile to oxygen or aluminum ion diffusion in the formed Al$_2$O$_3$ layer, with increased Al content in TiAlN films.

McNeil et al (1993) measured the frequency of Aluminium Nitride using first order Raman and analyzed width of principal Raman modes with increase in oxygen content.
Kuo et al (1994) used thin films of AlN in plasma source molecular beam epitaxy system and substrates and the thermal conductivity of these thin films was investigated by the thermal wave-mirage technique. A high value of 25.2 $\text{W m}^{-1}\text{K}^{-1}$ was found for the AlN film on Al$_2$O$_3$.

Qixin Guo and Akira Yoshida (1994) performed experiments on InN and AlN to determine the temperature dependence of band gap change in these materials. They conducted experiments at a wide range of temperatures and compared the Varshni equation and the Bose-Einstein expression with the experimental results. They concluded that the Nitride III-V compound semiconductors have smaller temperature dependence on band gap change.

Sanial et al (1995) measured the in-situ Raman spectra of aluminosilicate glasses and liquids with Albite (NaAlSi$_3$O$_8$) and Anorthite (CaAl$_2$Si$_2$O$_8$) compositions at high temperatures. They used a wire-loop heating device coupled with micro-Raman spectroscopy, in order to achieve effective spatial filtering of the extraneous thermal radiation.

Moller et al (1995) investigated a new type of low-power microheater module, based on diamond-like carbon and silicon carbide. They used finite element simulation methods to compare different types of concepts for low-power microheater modules. They also analyzed the thermal behaviour of membranes with different material combinations and the mechanical stress induced into a thin membrane at elevated temperatures.

Yoshihisa Watanabe et al (1996) synthesized Aluminium Nitride (AlN) thin films by evaporation of Aluminium and simultaneous irradiation with Nitrogen ions, at the substrate temperature of room temperature or 473K. They suggested that the synthesis of the AlN films with uniform surface was feasible by controlling the substrate temperature and the deposition rate.
Liu Ming et al (1998) measured the micro-Raman scattering by highly oriented crystalline Aluminum Nitride and found that the Raman scattering modes were broadened and shifted due to grain boundaries and other defects in the films. They compared the results with X-ray diffraction powder patterns and high-resolution transmission electron microscopy.

Logothetidis et al (1999) studied the process of oxidation on TiN films at various temperatures. They also studied the micro structural changes and compressive stresses in the films of TiN.

Kuball et al (1999) investigated the high pressure, high temperature annealing of Mg-P implanted GaN films at different temperatures using visible and ultraviolet micro-Raman spectroscopy. They monitored the structural quality and the stress in ion-implanted GaN films. They found no significant degradation effects occurred in GaN during annealing.

Moor P.De (1999) fabricated and analyzed a new material for highly resistive heaters on thin Ti/TiN layers. They conducted a thermal analysis and found a small temperature coefficient of resistivity. The temperature uniformity over the heater line was investigated using Emission Microscopy.

Huabin Wang et al (2001) analyzed the effect of additives on the oxygen content and the growth mechanism of self-propagating high-temperature synthesis (SHS) of AlN. They found that AlN grew from the vapour in the form of “platelet growth” at the lower oxygen content and with increasing oxygen content, the growing steps were blocked up by the impurities containing oxygen.
Oliveira et al (2001) studied the vibrational spectrum of AlN thin films by theoretical and experimental methods and analyzed low and high Raman modes of AlN.

Saito et al (2001) developed a new type of package for Planar Lightwave Circuit (PLC) devices. An AlN heater was incorporated into a package, in order to miniaturize the overall package size and, to improve its thermal properties. The thermal and mechanical properties of the package had been evaluated. They observed that the temperature uniformity within the temperature-controlled area on the surface of the AlN heater was within 1°C, and that the temperature stability of the surface of the AlN heater was within 0.4°C, when the ambient temperature was varied between -10°C and 70°C. They also found that the AlN heater had very good reliability. They examined that this package had high durability against mechanical vibration, mechanical shock and thermal shock.

Furjes et al (2002) studied the formation of thermally isolated integral micro-hotplates at elevated temperatures of 200-600 °C and they discussed the alternative processes, selection of the appropriate structural materials, formation of stable contacts to the filaments and deposition of gas-sensitive layers.

Long-Hao Li et al (2002) presented the influence of AlN on Titanium diboride (TiB₂) at a temperature of 1800 °C. When a small amount of AlN was added to the TiB₂, the Titania (TiO₂) present on the surface of the TiB₂ powder was eliminated by a reaction with AlN to form TiN and Al₂O₃. The elimination of TiO₂, improved the sinterability and consequently the mechanical properties of TiB₂. When too much AlN was added, the sinterability and the mechanical properties decreased, apparently due to the remaining unreacted AlN.
O’Shea et al (2002) conducted a test to obtain the Raman spectrum of crystalline SrTiO$_3$ in the temperature range 27 to 563 K and they characterized SrTiO$_3$ through the Raman peak.

Noveski et al (2003) studied the growth rate of AlN by investigating mass transfer effects and established a process for epitaxial growth on AlN seeds. They performed chemical analysis of impurities in the grown AlN boules and confirmed a very low oxygen contamination of 100 ppm wt, which makes it, suitable for high temperatures.

Yan-Ru Lin and Shinn-Tyan Wu (2003) investigated the growth of Aluminum Nitride on Al$_2$O$_3$ films at low temperature by sputtering process, using a 30 nm thick buffer layer of Aluminum and Titanium Nitride and found that epitaxial film could be deposited at room temperature if the buffer layer is Al.

Krishnan Balakrishnan et al (2004) studied the seeded growth of AlN single crystals on 6H-SiC substrates by sublimation and they examined the AlN nucleated as independent hexagonal islands and coalesced as growth progressed on. Growth rate of AlN grown on C-face SiC had been found to be higher than that on Si-face SiC.

Noveski et al (2004) developed a one-dimensional mass transfer model based on equilibrium sublimation and gas phase diffusion for high-temperature sublimation growth of AlN in an RF heated reactor and validated with growth results. They presented that the fast grain size development was achieved in the growth direction.

Zhong and Lye (2004) evaluated the effects of surface pre-coating and plasma treatment, because the heater surface profiles can affect the heat transfer efficiency from the heater surface to the wafer, when it is coated at
higher temperatures. The hot spots were identified at certain temperatures, which led to non-uniformity of the heater surface and a detailed study of the heater surface profiles and the manufacturing process is required to prevent hot spots and to improve heater performance.

Mohamed Azzaz and Amand George (2004) conducted an experiment on Aluminium Nitride (AlN) ceramics with a low oxygen content and found that AlN was deformed up to 10% strain in compression at elevated temperatures (1823-1923 K) under constant stress in the range 150-250 MPa.

Epelbaum et al (2004) presented the growth conditions for self-nucleation and subsequent growth of bulk AlN crystals by sublimation. They found that the natural habit of AlN crystals changes from needle-like to prismatic and then turns to thick asymmetric platelet, with increasing growth temperature. They also found that growth morphology and crystal quality were strongly influenced by the polar nature of AlN.

Creemer et al (2004) investigated Titanium Nitride as a heater material for MEMS hotplates and suggested that the Titanium Nitride was highly suitable for MEMS hot plates than the conventional Platinum hot plate.

Bei Wu et al (2004) studied the growth system of Aluminium Nitride, modeled and simulated the AlN bulk sublimation at various temperatures. Peter Lange et al (2005) studied the effects of temperature on micro heaters made of Ti/TiN stacks and pure TiN layers on bulk micromachined membranes. The pure TiN layers withstand temperatures up to 600 °C. This limitation is only given by the mechanical stability of the membrane stack, which is destroyed beyond this temperature.
Creemer et al (2005) investigated Titanium Nitride as a heater material for hotplates and microreactors as TiN is CMOS compatible, and has a higher melting point (2950 °C) than conventional heaters of Pt and poly-Si. They considered two types of TiN, high stress and low stress. The performance of Titanium Nitride was compared with that of Pt. They found that the maximum temperature of TiN coils is 11% higher than Pt coils with the same layout and over 700 °C. They also found that, for high-stress TiN, the TCR was almost constant and close to that of Pt, making it very suitable for temperature sensing and in the case of low-stress TiN, the TCR was nonlinear and changed its sign.

Lemme (2006) investigated TiN metal gate technology and optimized sputter process for stoichiometry. They found TiN/SiO$_2$ interfaces were chemically stable up to 800 °C and yielded excellent CV and IV characteristics.

Yazdi et al (2006) focused on growth dependencies, morphological forms and initial nucleation of Aluminium Nitride (AlN) crystals. They used optical microscopy and Scanning Electron Microscope (SEM) along with Atomic Force Microscope (AFM) to characterize the crystal surface morphology and they used Cathodoluminescence (CL) and X-Ray Diffraction (XRD) to determine crystal quality and crystallographic orientation of the grown crystals.

VanniLughi and David R. Clarke (2006) used Raman spectroscopy to characterize the residual stress and defect density of AlN thin films reactively sputtered on silicon. They found a correlation between the width of the Raman line, the oxygen concentration measured by secondary ion mass spectroscopy, and acoustic losses. They concluded that Raman could be used in Micro Electro Mechanical Systems (MEMS) applications, namely, acoustic attenuation and residual stress.
Trodahl et al (2006) investigated sputtered AlN films with directly measured biaxial strain by Raman spectroscopy to determine the strain dependence of the zone-center mode frequencies.

Heil et al (2006) deposited Titanium Nitride films by a plasma-assisted atomic layer deposition (PA-ALD) process, at temperatures ranging from 100 to 400°C. They studied the plasma by optical emission spectroscopy and Langmuir probe, and obtained an ion density of $10^9$ cm$^{-13}$ and an electron temperature of 3.5 eV just above the substrate.

Meilin Gu et al (2006) investigated the microstructure and mechanical properties of the TiB$_2$ - TiN composites at high pressure and temperature. TiN can improve the bonding strength among the TiB$_2$ grain boundaries and change the fracture pattern from intergranular to transgranular fracture with the increase in TiN and it gives best mechanical properties at high temperature and pressure.

Hiroyuki Fujiki (2007) developed new thin-film Planar Multi-Junction Thermal Converters (PMJTC) to improve the high-frequency AC-DC transfer differences. The heater resistor and thermocouples of these PMJTCs were produced on different substrates. By using a high thermal conductivity AlN substrate they obtained almost the same sensitivity as that of PMJTCs on silicon.

Zhang et al (2007) developed a thin film Gold/Titanium (Au/Ti) microheater for microthruster ignition, micro explosive boiling, and micro sensor applications. They fabricated microheater onto a Pyrex bulk substrate using a micro-fabrication technology and they used the finite-element based electro-thermal modeling to predict the microheater performance. They studied the variations of the microheater temperature with time, space, and power supply from the modeling and presented a method to determine the
thin film Au/Ti electrical resistivity and thermal conductivity. They validated the finite-element model by the experimental measurements.

Yin et al (2007) studied the thermal oxidation properties of Titanium Nitride and Titanium-Aluminum Nitride materials at different temperatures. They found that TiN or TiAlN as an element were not suitable candidates for use as solar selective absorbers in air-stable high temperature applications.

Chaudhuri et al (2007) investigated dry thermal oxidation of low defect density aluminum nitride single crystals by high resolution transmission electron microscopy (HRTEM) and electron energy loss spectroscopy (EELS). They found that the oxidation at 800 °C produced an amorphous oxide layer and oxidation at 1000 °C produced a crystalline, epitaxial oxide layer with several large grains and twin structures. They also found that AlN crystal structure was nearly defect- and oxygen-free.

Spannhake et al (2007) studied the MEMS heater for different applications at different range of temperatures and proposed a new material SnO$_2$: Sb for MEMS heater which is suitable for medium and high temperatures.

Creemer et al (2008) investigated Titanium Nitride as a heater material for microhotplates and microreactors and they found that the working temperature of Titanium Nitride hotplates is 11% higher than Platinum hotplates and the failure of TiN heaters is due to rupture of the material.

Renu Dhunna et al (2008) developed thin films of Aluminum Nitride by ion beam sputtering in an Ar-N$_2$ atmosphere on Si substrate and the films have been characterized by Grazing Incidence X-ray Diffraction
(GIXRD), X-ray Reflectometry (XRR), Atomic Force Microscopy (AFM) and Optical Spectroscopy and they examined that the band gap of irradiated films of Aluminum Nitride decreases due to the increase in metal content at the surface.

Gwiy Sang Chung and Jae Min Jeong (2009) described the fabrication and properties of polycrystalline 3C-SiC micro heaters built on AlN(0.1 μm)/3C-SiC(1.0 μm) suspended membranes using surface micromachining technology. They found that the 3C-SiC micro heaters stand at higher applied voltages than in case of Pt micro heaters.

Machunze (2009) studied the stresses and texture on TiN by high power impulse magnetron sputtering (HIPIMS) on silicon substrates.

Guan et al (2010) fabricated a thin film Silver/Titanium microheater with a four-point probe, double spiral geometry for MEMS applications on a silica glass substrate. They found that an operating temperature of 333 K can be achieved with a mere 5 μA, which is very low power for MEMS heater applications.

Vasu et al (2011) studied the crystal structure and optical properties of TiN thin films deposited on quartz substrate from room temperature till 600 °C, with increasing temperature, the crystal structure changed from tetragonal to cubic, with increasing the substrate temperature.

Groenland et al (2012) presented test structures for the electrical characterization of ultrathin conductive films based on electrodes on which the ultrathin film is deposited. They discussed two different designs, a novel design with buried electrodes and a conventional design with electrodes at the surface.
Xiao-Lei and ANG Li-Ying (2012) sintered Aluminum nitride ceramics are by high-pressure technology and observed the microstructure by SEM. They found that the AlN powder grew into full crystal grains with uniform size, the crystal particles were in a regular hexagonal structure, and the grain boundary phases were clean without gas phase.

2.3 **RAMAN SPECTRA OF HEATER MATERIALS**

Raman instruments rely on inelastic scattering, or Raman scattering, of monochromatic light, usually from a laser in the visible, near infrared, or near ultraviolet range. The laser light interacts with molecular vibrations, phonons or other excitations in the system, resulting in the energy of the laser photons being shifted up or down. The shift in energy gives information about the vibrational modes in the system (Raman et al 1928). Typically, a sample is illuminated with a laser beam. The Raman signals have considerable effects in crystals structures and influence the material properties (Raman et al 1929). The change in properties of the materials can be obtained using these Raman scattering effects (Loudon 1964, John R. Ferraro 2003 and Jimenez-Sandoval 2000).

Hirschfeld and Chase (1986) studied the feasibility of Fourier transform Raman spectroscopy. They concluded that the Fourier transform Raman spectroscopy was a single instrument which combines the features of both complementarity of IR and basic Raman spectroscopy.

Burgio et al (1998) analyzed the various types of Raman spectrosopes and possible applications of Raman spectroscopy.
Raman spectroscopy is a non-invasive and non-destructive, and can be used to analyze a wide range of substances, with no requirements for sample composition or labeling prior to analysis. Stand-off Raman analysis not only removes the need for contact but also allows samples to be measured in-situ, distinct advantages in most of the engineering applications (Alison et al 2009).

Raman spectroscopy is useful in determining the structural change of the materials under high pressure and temperature. When the materials are subjected to high temperature, there is a structural change in the materials and subsequently the materials loose its thermal stability (John R Ferraro et al 2003).

Sanial (1995) presented the high temperature Raman spectroscopic studies of Aluminium in the silicate network to determine the structural and thermal stability at high temperatures.


Jimenez-Sandoval (2000) presented a brief overview of Raman spectroscopy technology in traditional spectrometers and different applications of modern micro-Raman spectroscopy to study of materials, ranging from epitaxial semiconductor thin films to the optoelectronics industry, biomaterials to medical science.

Long Derek (2002) presented a unified theoretical treatment, which was complete and rigorous. They also concluded that theoretical treatment required a variety of mathematical and physical tools.
Kouteva-Arguirova et al (2003) studied the strong local heating by the tightly focused laser beam results in an unexpectedly small temperature shift of the Raman peak. They discussed the experimental results of shift, broadening, and asymmetry, in view of restricted thermal expansion and a temperature dependent Raman cross section.

Fischbach (2003) performed the Raman scattering test on different carbon materials at different temperatures and obtained the effects of temperature on structural properties of these materials.

Xiaojun Li et al (2006) measured the Raman spectra of Aluminium Nitride over the temperature range from room temperature to 1273 K and found that the Raman peaks of two selective modes are shifted toward lower frequency with temperature, which indicate that the compressive stress in the compact of Aluminium Nitride relax gradually when temperature increased. It was also found that the decomposition starts at high temperature only, around 1273 K and no effect of Raman spectra was observed at lower temperature ranges.

Remédios et al (2010) performed Raman scattering test on KDP:Mn (0.9% weight of Mn) crystal and the temperature dependency of the crystal was found.
2.4 FINITE ELEMENT METHOD

Driven by the development of powerful and inexpensive computers, the field of computer aided engineering emerged. It provides predictive tools as well as insights into complex engineering processes. Hence, engineers working in many different application areas demand numerical solution tools for their investigations which some years ago were only accessible by experiments. Modeling of engineering problems lead in many cases to ordinary and partial differential equations which often are of linear nature. A powerful tool to solve these differential equations is the finite element method which was developed over the last 50 years (Peter Wriggers 1999).

Finite element analysis, also called the finite element method, is a method for numerical solution of field problems. A field problem requires the determination of spatial distribution of one or more dependent variables. Mathematically, a field problem is described by differential equations or by an integral expression. Description may be used to formulate finite elements which can be visualized as small pieces of a structure (Cook et al 2003). The elements are connected at points called 'Nodes'. The assemblage of elements is called finite element model or structure. The particular arrangement of elements is called a mesh.

Numerically, a finite element mesh is represented by a system of algebraic equations to be solved for unknowns at nodes. Finite element modeling is the process of preparing a computational model. It decides about the significant features of the actual problem that can be incorporated in the model. Simulation is the prediction of the intended output results of the Computational Finite Element model (Singiresu S. Rao - 2007).
Moller et al (2002) investigated a large number of gas-sensitive materials like semiconducting metal oxides operate only at elevated temperatures. They used simulation methods (finite-element method, FEM) to compare different types of concepts for low-power microheater modules.

### 2.5 FINITE ELEMENT SIMULATION OF MTCH

Moller et al (1995) investigated a new type of low-power microheater module based on diamond-like carbon and silicon carbide. They used finite element simulation methods to compare different types of concepts for low-power microheater modules. They also analyzed the thermal behaviour of membranes with different material combinations and the mechanical stress induced into a thin membrane at elevated temperatures.

Inderjit Singh and Mohan (2005) designed micro-hotplates and carried 3D simulations and electro-thermal analysis using Coventorware for gas sensor applications.

Crosby and Guvench (2009) developed finite element computer models of MEMS microheater structures to predict their performance accurately for use as a design verification and optimization tool. They have taken the primary performance criteria for the microheaters as temperature uniformity, high heating efficiency and fast thermal response time and the models of SOI-MEMS micro-heaters were developed employing COMSOL Multiphysics platform.

Velmathi and Mohan (2009) designed and fabricated a micro heater structure for uniform thermal distribution and low power consumption and they performed the finite element simulation using COMSOL Multiphysics software and the temperature distribution across the heater
dimension was validated by conducting experiments in the fabricated microheater structure.

Salvi et al (2010) presented numerical Modeling of Continuous Flow Microwave Heating using COMSOL and ANSYS and the results were compared.

Velmathi et al (2010) developed a 2D microheater model for gas sensor applications and performed simulations and electro-thermal analysis of micro-heater designs using COMSOL Multiphysics software and the dimensional parameters were optimized and the temperature variations were studied for different electrical inputs.

Velmathi et al (2010) designed a microheater and carried 3D electro-thermal analysis using COMSOL for gas sensor applications.

Vineet Bansal et al (2010) designed the microheater and performed geometric optimization by using COMSOL MULTIPHYSICS 4.1. They presented three different spiral patterns of micro-heaters using platinum as a heating material and these micro-heaters were designed to ensure low power consumption, low thermal mass, low stress and low thermal expansion, better temperature uniformity and fast response times and a comparative analysis of these results was carried out.

Dr. Thomas Frommelt (2010) used Comsol multiphysics and Matlab for material characterization and process analysis.

Woo-Jin Hwang et al (2011) presented a novel design of a poly-Si micro-heater to improve the uniformity of heat dissipation on the heating plate and the optimization of the heater was performed using COMSOL Multiphysics. By using the power compensated design, the uniform heating area was increased by 2.5 times and the average temperature was increased to 40°C and which was suitable for a semiconductor gas sensor. Meanwhile, the poly-Si micro-heater without compensation showed a higher level of infrared radiation under equal power consumption conditions.

Dinesh Kumar et al (2011) designed a 3D spiral type microheater for low power gas sensing applications and carried out the electro-thermal simulation and geometrical optimization using COMSOL software. The uniform temperature profile and the power consumption of the heaters for the supply voltage of 2V, to obtain a temperature of 450°C was analyzed for all the patterns and results were compared.

Cesare de et al (2012) proposed the use of an array of amorphous silicon diodes to monitor the spatial temperature distribution over a thin film heater used for thermal treatments in lab-on-chip systems. The effects of heater geometry and operating conditions on the spatial temperature distribution were preliminarily investigated by using COMSOL Multiphysics, coupling the electrostatic problem with the thermal problem via the Joule effect.

2.6 EXPERIMENTS

Abid et al (1986) conducted a test on AlN to determine the thermal stability of the material by conducting an electro-thermal test and they presented the possibility of the AlN material for high temperature applications.
Kuball et al (1998) investigated the structural stability of GaN at different temperatures and they performed an electro-thermal test on the material and found that the GaN is suitable for high and medium temperature applications.

2.7 CONCLUSION

A detailed literature survey has been made on the following areas in order to determine a suitable material for medium and high temperature applications of micro tubular coil heater.

- Possible micro tubular coil heater materials which are suitable for high and medium temperature applications. The materials considered for the analysis are Gallium Nitride, Titanium-Aluminium Nitride, Strontium Nitride, and Hafnium Nitride. Various properties had been taken for heater materials and based on the analysis carried out; Titanium Nitride and Aluminium Nitride were selected for heater materials.

- Application of Raman spectroscopy to determine the thermal stability of the materials

- Finite element simulation of different heater materials

- Experiments to find the temperature pattern for different electrical inputs and to validate the finite element results.