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"MEMS Based Micro Heaters in Fiber Tapering"

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Abstract: *The number of applications for MEMS micro-heaters devices is increasing rapidly as they are key components in sub-miniature micro-sensors, especially in gas sensors. The metal oxide gas sensors utilize the properties of surface absorption to detect changes in resistance as a function of varying concentration of different gases.So there proper design is of critical importance. They are designed considering factors such as power consumption, temperature uniformity etc. MEMS micro-heaters make use of low power and produce efficient thermal dissipation there by helping in fiber tapering without the loss of fiber. MEMS CAD tool come in handy for this design and analysis.*[1]
Keywords:*MEMS,CAD tool*

I. Micro - Heaters

A micro-heater is a small high power heater with precise control that can offer temperature in excess of 1000 C. The heating method of micro-heater involves conversion of "electrical work to high density heat". These high temperatures influence various factors such as "conductance of the film" and "quantity of gas absorbed". They are mainly used for detecting large number of gases by coating with different sensing films. The applications of micro-heaters are in wide fields like gas sensors, RF applications, Material testing and characterization and in fiber optics for the reduction in diameter of fiber. They come in different patterns such as meander type, plan plate with central square hole, S-shape, fan shape and double spiral. A fiber tapering process can be done with the help of MEMS micro-heaters and fiber couplers can be fabricated by means of this method. MEMS is a process in which miniaturization of devices is possible by which the disadvantages of the original devices is overcome.

Meander

Fig 1: Meander Structure

II. Working Of Micro-Heaters

Micro Heaters are the most important devices in the field of high temperature gas sensing devices since they allow the reduction of the sensor power consumption and also enable in temperature modulation of the gas sensing in performance improvement of gas selectivity. They work on the principle "Joule heating effect". In Joule heating, the temperature ^ is due to resistance heating from the electric current. The electric potential V is the solution variable in the conductive media DC application mode. The generated resistance heat Q is proportionalto the square of the magnitude of the electric current density J. Current density, in turn is proportional to the electric field, which equals the negative of the gradient potential V. [2]

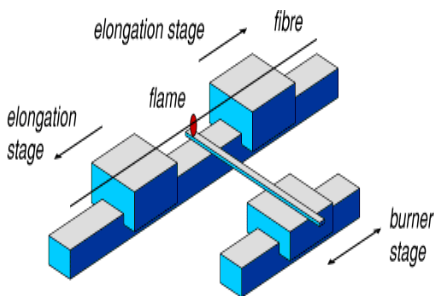

Fig2 : Taper Rig Arrangement

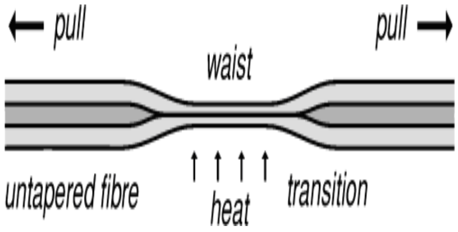

Fig3 : The Tapering Process

Fiber Tapering Process

Fiber tapering is a convenient and effective way of dramatically varying the nature of a fiber waveguide, while introducing hardly any loss of light. The fiber is placed in a "taper rig", where two motorized stages, stretch the fiber while a part of it is heated by a small flame. The heated part therefore narrows to form a waist that is connected to untreated fiber ends by taper transitions. The whole resulting structure is called a "tapered fiber" or a "taper". If taper waist is less than 20-30 mm is diameter, the light spreads out from the shrinking fiber core to fill the fiber as it propagates along the input transition and into the waist. The opposite happens at the output, the light being captured by the growing fiber core.

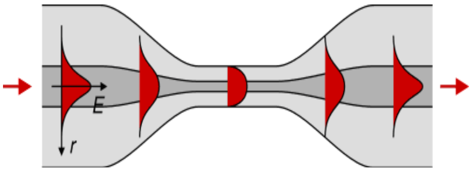

Fig 4: Interior of a Fibre

Mathematical Modelling

The Joule heating model node in COMSOL uses the following version of the heat equation as the mathematical model for heat transfer in solids:

$$\mathbf{Q \;\alpha\; |J|^2}$$

Where, Q – Amount of heat in Joules

J – Current Density in (A/m2)

The coefficient of proportionality is the electrical resistivity ρ**= 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 according to:

$$\sigma = \frac{\sigma_0}{1 + \alpha(T - T0)}$$

Where $\sigma_0$is the conductivity at the reference temperature T_0 and σis the temperature coefficient of resistivity, which describes how the resistivity varies with temperature.

Also the power consumption is calculated using the formula: $P = \frac{V^2}{R}$

Where, V – Voltage applied (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. The resistance of the heater can be calculated using the formula:

$$R = \frac{\rho l}{wt}$$

Where, l – Length of the heater (in m)

w –width of the heater (in m)

The Equations have been solved under Neumann, and mixed boundary conditions numerically using the Finite Element method (FEM) when the electro-thermal module is selected in COMSOL. Fixed temperature and potentials are assumed at the ends of the heater.[3]

III. Experimental Analysis

Various factors including temperature, current and stress have been identified with the help of COMSOL tool.

Temperature Profile

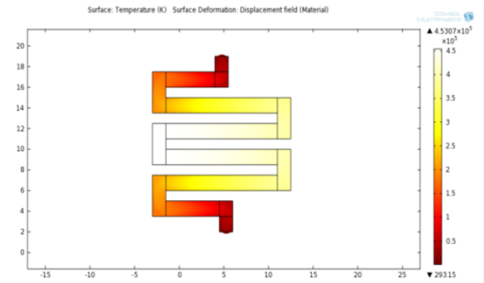

Fig 5: Temperature Profile

It is seen from the above representation that the temperature is higher at the centre of the meander structure and symmetric about the ends.

Current Density Profile

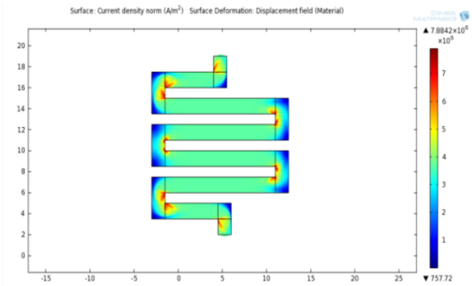

Fig 6: Current Density Profile

Current density seems to be even along the entire structure except at the corners.

Stress Profile

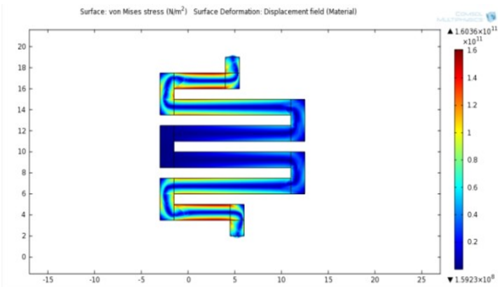

Fig 7: Stress Profile

Stress is even in the centre and comparatively less there while at the ends is slightly high.

Graph

The following graph shows the variation in temperature with respect to distance.

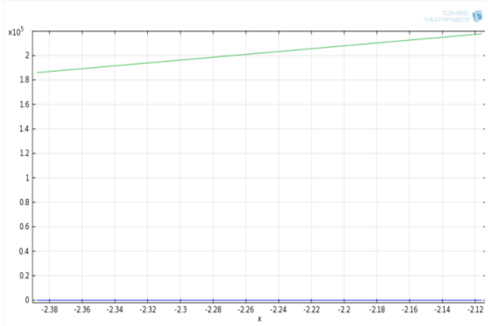

Fig 8: Graphical representation of temperature with distance

IV. Conclusion

The structure is designed and the parameters like temperature, current density and stress have been applied and the corresponding results have been obtained. Thus the microheater can be used in the fibre tapering process in which the amount of light entering the fibre wave guide is enhanced by reducing the diameter of the core of the fibre due to which less light is lost, consequently increasing the optical efficiency.

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