

DEVELOPMENT OF LEAF SHAPE MICROCHANNEL HEAT SINK BY EDM TECHNIQUE AND FINDING EFFECT OF MATERIAL REMOVAL RATE AND SURFACE ROUGHNESS ON EDM PARAMETERS

Mahesh B. Mohite¹, Prof. V. P. Gaikwad²

¹PG Scholar, ²Professor, Department of Mechanical Engineering,

D.K.T.E. 'S TEI Ichalkaranji, (India)

ABSTRACT

Lots of researches are being carried out on fabrication technique of microchannel Heat Sink. Because of its complex geometry shape it is very difficult to fabricate microchannel Heat Sink. This paper provides different fabrication techniques for Microchannel Heat Sink and also investigated the development of leaf shape microchannel Heat Sink by EDM technique and find out effect of Material Removal Rate and Surface Roughness on EDM parameters. EDM technique is most suitable technique for fabrication of Microchannel Heat Sink. EDM technique is easier and time consuming technique for fabrication of leaf shape Microchannel Heat Sink.

Keyword: Microchannel Heat Sink, EDM, Bulk etching, deep reactive ion etching, microchannel, micro fabrication, wafer bonding, Material Removal Rate, Surface Roughness.

I. INTRODUCTION

There are different shapes of microchannel like square; triangular, trapezoidal are used for cooling purpose. Because of their high area-to-volume ratio, and also due to area enhancement microchannel heat sinks are strong candidates for the effective dissipation of heat from devices, such as, integrated circuits. Microchannel heat sinks are utilized generally with liquid coolants which provide higher heat transfer coefficients compared to gaseous coolants. The heat is removed from the surface either by single-phase liquid flow or phase change of the coolant with flow boiling (two-phase flow). The unique characteristics of microchannel heat sinks (small length scales, conductive substrate, abrupt contraction/expansion at the entrance/exit, and high pressure drop) give rise to conditions that are quite different from those of conventional channels. Microchannel are used for cooling purpose in several scientific and commercial applications like Micro-Electro-Mechanical System (MEMS), Electronic cooling system, Biomedical Engineering; Miniaturization and Biochemistry etc. The fabrication of Microchannel Heat Sink is very difficult task because of its complex and small scale geometry. This paper listed different fabrication process and also investigated the development of leaf shape Microchannel Heat Sink by using EDM technique and find out effect of Material Removal Rate and Surface Roughness on EDM

parameters. EDM technique is easier and time consuming technique for fabrication of leaf shape Microchannel Heat Sink.

II. FABRICATION TECHNIQUES FOR MICROCHANNEL

Micro-channels can be generally fabricated by two different techniques [1]

1. Miniaturized Traditional Technique

2. Modern Technique

Traditional Technique, consists of conventional machining which are miniaturized to use them in micro regime e.g. Micro EDM, Stereo lithographic fabrication, electroforming, molding, ultrasonic and water jet machining, electroforming are key processes of this type.

Modern Technique mainly contains Focused Ion Beam, Laser Machining, Isotropic and anisotropic wet chemical etching is some examples of fabrication based on silicon. LIGA (Lithography, Galvanofarming, Abforming means Lithography, Electroplating & Molding) is fabrication process which is based on lost wax molding technique mainly it is a high aspect ratio. This is used for micro-structures fabrication of high aspect ratio with compromising to their surface finish and quality.

Hybridfabrication eg.Wafer bonding in which different etched shaped wafers are bonded together to form micro-channels.

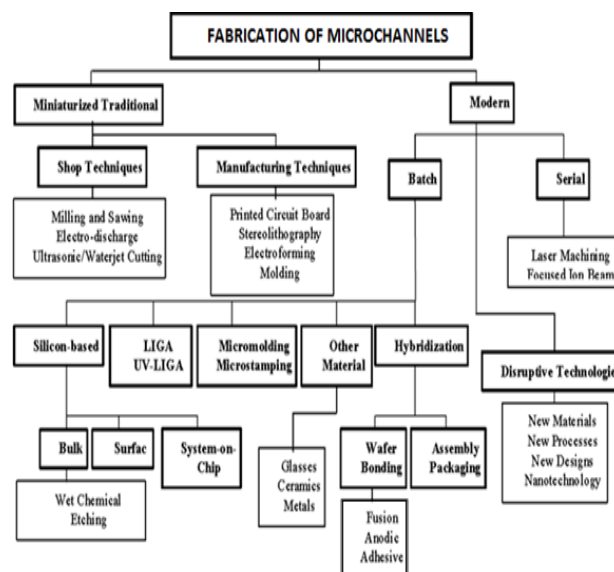


Fig.1 Different Fabrication Techniques

III. FUNDAMENTALS OF EDM PROCESS

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.[2-4]

3.1 Process

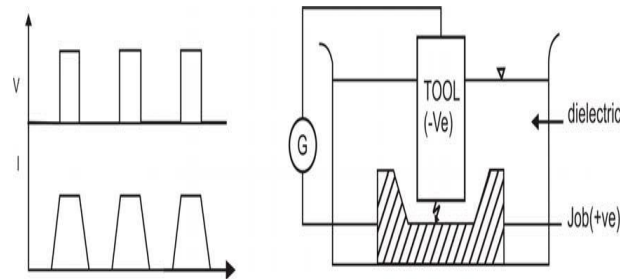


Fig.2 Schematic representation of the basic working principle of EDM process

In EDM, a potential difference is applied between the tool and work piece. Both the tool and the work material are to be conductors of electricity. The tool and the work material are immersed in a dielectric medium. Generally kerosene or deionized water is used as the dielectric medium. A gap is maintained between the tool and the work piece. Depending upon the applied potential difference and the gap between the tool and work piece, an electric field would be established. Generally the tool is connected to the negative terminal of the generator and the work piece is connected to positive terminal. As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces. If the work function or the bonding energy of the electrons is less, electrons would be emitted from the tool (assuming it to be connected to the negative terminal). Such emission of electrons are called or termed as cold emission. The “cold emitted” electrons are then accelerated towards the job through the dielectric medium. As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules. Such collision may result in ionization of the dielectric molecule depending upon the work function or ionization energy of the dielectric molecule and the energy of the electron. Thus, as the electrons get accelerated, more positive ions and electrons would get generated due to collisions. This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap. The concentration would be so high that the matter existing in that channel could be characterized as “plasma”. The electrical resistance of such plasma channel would be very less. Thus all of a sudden, a large number of electrons will flow from the tool to the job and ions from the job to the tool. This is called avalanche motion of electrons. Such movement of electrons and ions can be visually seen as a spark. Thus the electrical energy is dissipated as the thermal energy of the spark.

The high speed electrons then impinge on the job and ions on the tool. The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux. Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000 °C.

Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting. The molten metal is not removed completely but only partially. [6-8]

As the potential difference is withdrawn as shown in Fig. 2 the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

Thus to summarize, the material removal in EDM mainly occurs due to formation of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference.

Generally the workpiece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal. Similarly, the positive ions impinge on the tool leading to tool wear.

In EDM, the generator is used to apply voltage pulses between the tool and the job. A constant voltage is not applied. Only sparking is desired in EDM rather than arcing. Arcing leads to localized material removal at a particular point whereas sparks get distributed all over the tool surface leading to uniformly distributed material removal under the tool.

IV. DIFFERENT SHAPES OF MICROCHANNEL HEAT SINK

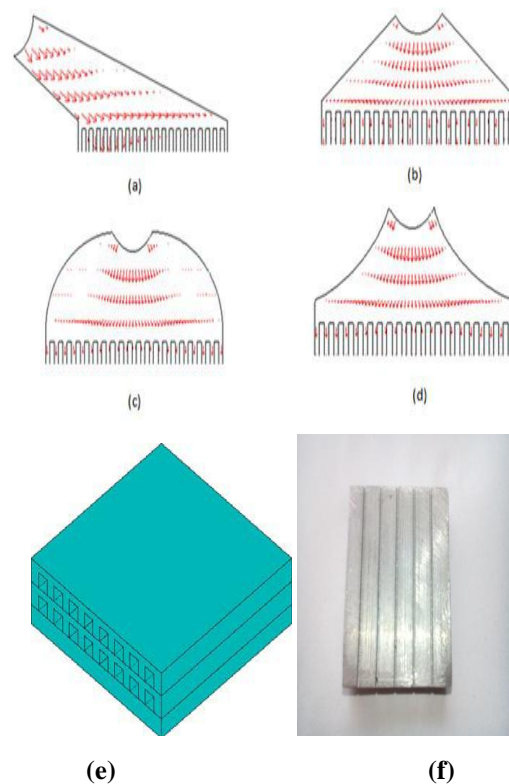


Fig.3A) Side entrance and a triangular shaped fluid distribution. B) Fluid inflow in the central part and distribution in triangular. C) Distribution is of convex shape and central inflow. D) Concave shape geometry. E) Trapezoidal shape. F) Square shape.

V. DEVELOPMENT OF LEAF SHAPE MICROCHANNEL HEAT SINK

The rate of liquid coolant flowing through natural leaf shape channel is more than the square, triangular shape channel and also it required minimum time to cover maximum surface area of channel. So in the current work leaf shape Microchannel is selected for cooling purpose. The designs for leaf shape Microchannel were prepared on CATIA R20 Software. The design of natural leaf shape Microchannel is shown in figure 4.

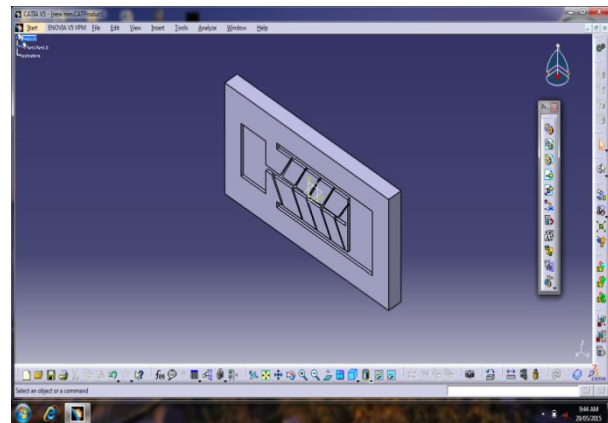
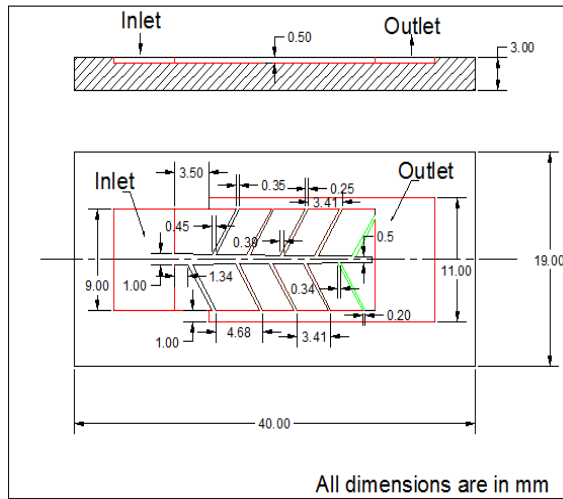


Fig.4 Design for leaf shape microchannel Heat Sink Fig. 5 3D Model for Microchannel

VI. DEVELOPMENT OF EDM ELECTRODE

With the help of designed drawing of leaf shape microchannel, the design of electrode is developed and manufactured it on CNC machine. The details design of electrode is shown in figure 6.

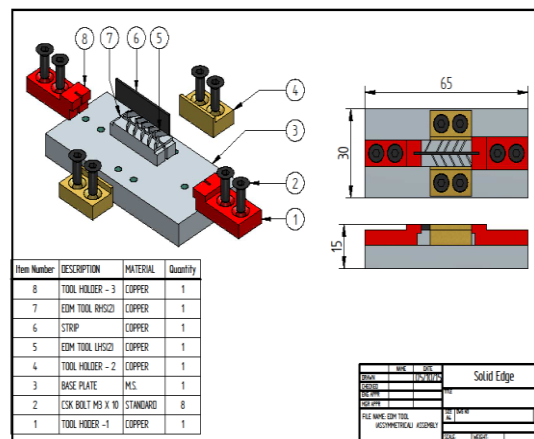


Fig.6Detail design of electrode.

After designing the design for tool, the tool is manufactured on CNC machine. The figure 7 shows developed Copper electrode.

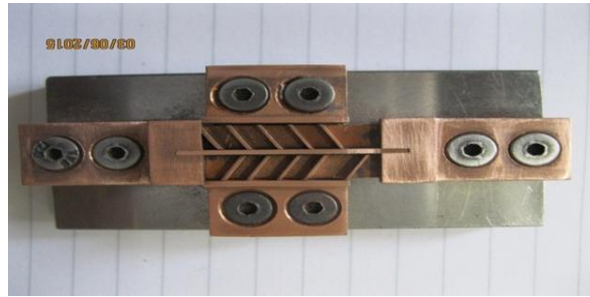


Fig.7 Image of Developed Electrode

Machine is provided with fixed pulse voltage. The current, pulse ON time and pulse OFF time were selected from the range. Table1 show the Machine specifications.

Table 1 Machine specifications

Description	Details
Supply voltage	75V
Discharge current	30A
Servo system	Electromechanical
Power consumption	2kW
Model	ELECTRONICA

VII. FABRICATION PROCESS



Fig. 8 EDM machine

Detail manufacturing process is shown in following figure stepwise



Fig. 9 Holding of Electrode



Fig.10 Parallality checking of electrode Fig. 11 Fabrication process of Microchannel Heat Sink

Nine work piece samples were fabricated by EDM process and studied the effect of current, T-ON and T-OFF on the Material Removal Rate and Surface Roughness. Material Removal Rate is calculated by equation 1.

$$MRR = \frac{(W_i - W_f) \times 1000}{(D_w \times t)} \quad (1)$$

MRR – Material Removal Rate (mm³/min)

W_i- Initial weight of work piece (gm.)

W_f- Final weight of work piece (gm.)

D_w- Density of the work piece (gm./cm³)

t - Period of trial (min) [9]

The parameter mostly used for general surface roughness is Ra. It measures average roughness by comparing all the peaks and valleys to the mean line, and then averaging them all over the entire cut-off length. The surface roughness is measured by surface roughness tester machine, which is shown in Fig.12



Fig.12 Equipment for Surface Roughness Measurement

By taking different range of current i.e. 2, 3, 5 Amp. T- ON 30, 50, 90μs and T-OFF 5, 7, 9μs the work piece were fabricated. The fig. 13 shows nine samples are fabricated for experiment.[12-14]



Fig.13 Samples fabricated for experiment

VIII. TESTING OF FABRICATED WORK PIECE.

After fabrication of work piece on EDM machine it is very essential to check the dimensions of microchannel are within the tolerance or not. So the dimension of microchannel is checked by microscope machine. The microscopic images of work piece are shown in figure 14.

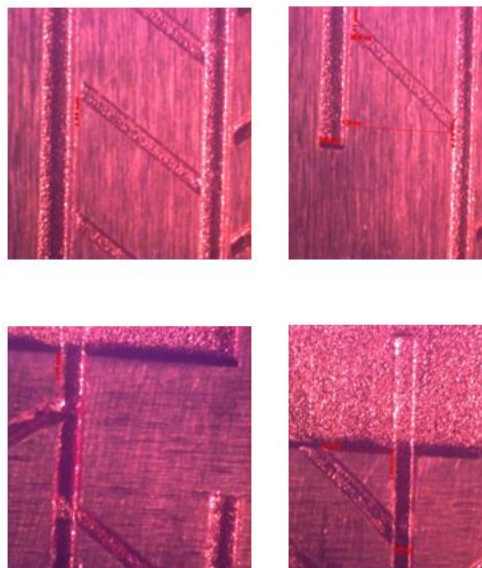


Fig. 14 Microscope images of work piece

The microscopic images give the confirmation about work piece. The dimensions show clearly that work piece are within required tolerances so, work piece is acceptable. After fabrication it is also important to check whether the liquid coolant is passed through channel or not. The experimental performance is carried out for checking flow of coolant through channel. The following images show the coolant is easily passed through channel.

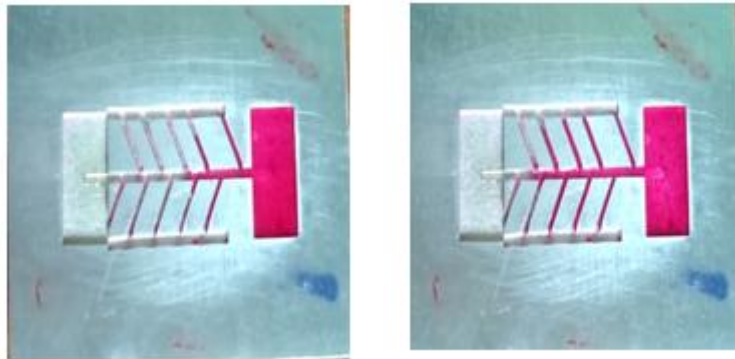


Fig.15 Checking flow of coolant through channels

IX. EXPERIMENTAL RESULTS

Table 2 Experimental Observation and S/N ratio for MRR and Surface Roughness.

Exp. No	Response values		S/N ratios	
	MRR (mm ³ /min)	SR (μm)	MRR (dB)	SR (dB)
1	0.0105	1	-39.5762	0
2	0.0085	1.01	-41.4116	-0.0864
3	0.0082	0.955	-41.7237	0.3999
4	0.0105	1.025	-39.5762	-0.2144
5	0.0102	0.995	-39.8279	0.0435
6	0.0138	1.04	-37.2024	-0.3406
7	0.0105	1.085	-39.5762	-0.7085
8	0.0140	1.09	-37.0774	-0.7485
9	0.0105	1.1	-39.5762	-0.8278

Experimental observation table shows the MRR is high at eighth experiment means at 5 Amp. Current and minimum value of SR at current 2 Amp. It means the as the current increase the rate of material removal is high.

X. CONCLUSIONS

The following conclusions were drawn from above work as;

- 1] For fabrication of leaf shape microchannel heat sink the EDM technique is most suitable technique.
- 2] By using developed EDM tool the fabrication process become easier and time consuming process.
- 3] As the current increase the rate of material removal is increase. The higher material removal rate is obtained at 5 Amp. Current i.e. 0.0140
- 4] And lower surface roughness is obtained at 2 Amp. Current i.e. 0.955

REFERENCES

- [1]. GauravRaghav, B.S. Kadam, Manjeet Kumar, “Optimization of Material Removal Rate in Electric Discharge Machining Using Mild Steel”, International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-1, Issue-7, May 2013.
- [2]. Dhirendranathmishra ,Aarti Bhatia ,Vaibhavrana , “Study on Electro Discharge Machining (Edm)”, The International Journal Of Engineering And Science (IJES), ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805.
- [3]. KuldeepOjha, R. K. Garg,K. K. Singh, “MRR Improvement in Sinking Electrical Discharge Machining: A Review”, Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.8, pp.709-739, 2010.
- [4]. Yan-Cherng Lin &Ho-Shiun Lee, “Optimization of machining parameters using magnetic-force assisted EDM based on gray relational analysis”, Int J AdvManufTechnol (2009) 42:1052–1064.
- [5]. K. M. Patel &Pulak M. Pandey& P. VenkateswaraRao,“Optimisation of process parameters for multi-performance characteristics in EDM of Al₂O₃ ceramic composite”, Int J AdvManufTechnol (2010) 47:1137–1147.
- [6]. T. A. El-Taweel, “Multi-response optimization of EDM with Al–Cu–Si–TiC P/M composite electrode”, Int J AdvManufTechnol (2009) 44:100–113.
- [7]. E. Aliakbari& H. Baseri,“Optimization of machining parameters in rotary EDM process by using the Taguchi method”, Int J AdvManufTechnol (2012) 62:1041–1053.
- [8]. Yusuf Keskin. H. Selc,ukHalkacıMevl ıt Kizil,“Anexperimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining (EDM)”,Int J AdvManufTechnol (2006) 28: 1118–1121.
- [9]. Ai-HueiChiou& Chung-Chen Tsao& Chun-Yao Hsu, “A study of the machining characteristics of micro EDM milling and its improvement by electrode coating”, Int J AdvManuf Technol.
- [10]. S. Singh, “Optimization of machining characteristics in electric discharge machining of 6061Al/Al₂O₃p/20P composites by grey relational analysis”, Int J AdvManufTechnol (2012) 63:1191–1202.
- [11]. C. Anbumeenakshi, M. R. Thansekhar, (2014) “Experimental Investigation of the Combined Effect of Coating and Header Combination in Microchannel”, 2nd International Conference on Innovations in Automation and Mechatronics Engineering, 520 – 527.
- [12]. Mushtaq Ismael Hasan, Hayder Mohammed Hasan, Ghassan Adnan Abid, (2014) “Study of the axial heat conduction in parallel flow”, Journal of King Saud University – Engineering Sciences 26, 122–131.
- [13]. DeewakarSharmaa, ParbarPratham, Singha, Harry Gargb, (2013) “Comparative Study of Rectangular and Trapezoidal Microchannels Using Water and Liquid Metal”, Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference, 791 – 796.
- [14]. Md. Jane Alam Khan, Md. RakibulHasan, Md. ArifHasanMamun, (2013) “Flow behavior and temperature distribution in micro-channels for constant wall heat flux”, 5th BSME International Conference on Thermal Engineering, 350 – 356.