Feasibility of microchannel heat sink fabrication using low speed Micro End-Mill and Wire-Cut EDM

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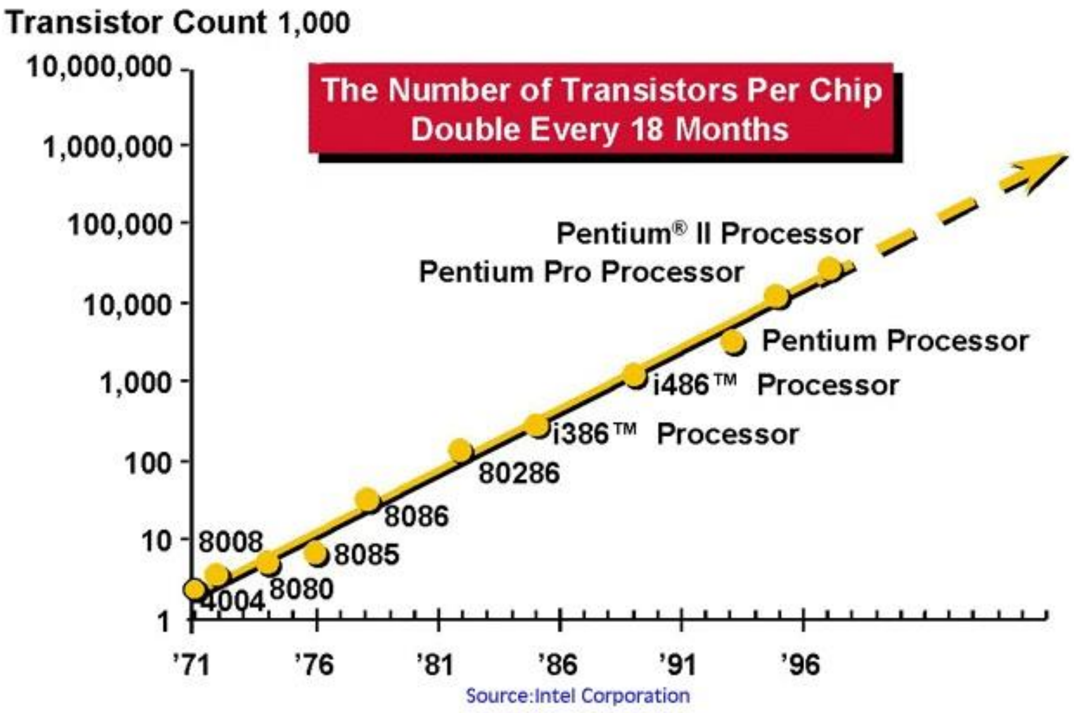
INTRODUCTION

Moore's Law



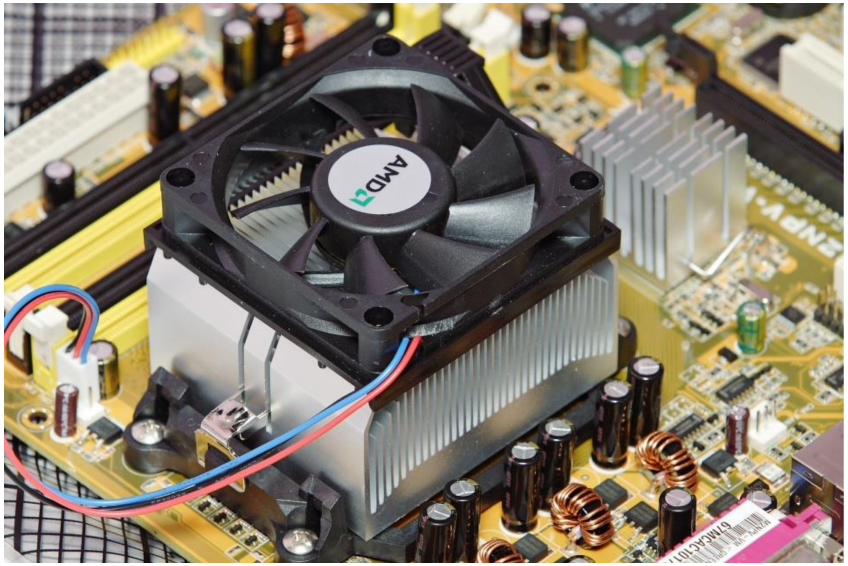
Thermal management

- Higher rate of heat dissipation
- Tiny surface area
- High heat flux

Limited capabilities of traditional air heat sink to remove heat

Moore, Gordon E., Cramming more components onto integrated circuits, Electronics Magazine (1965), p. 4.

INTRODUCTION

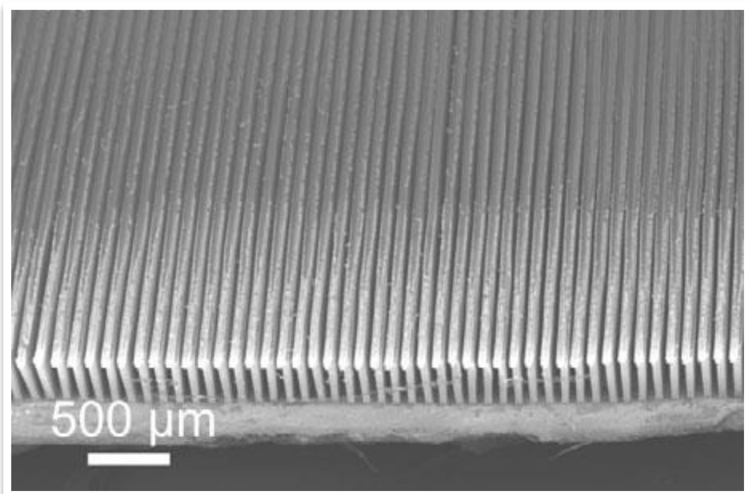


Classical air cooling

- Low heat transfer coefficient

Micro-channel heat sink

- Large surface-to-volume ratio
- Thermal boundary layer development
- Higher pressure drop



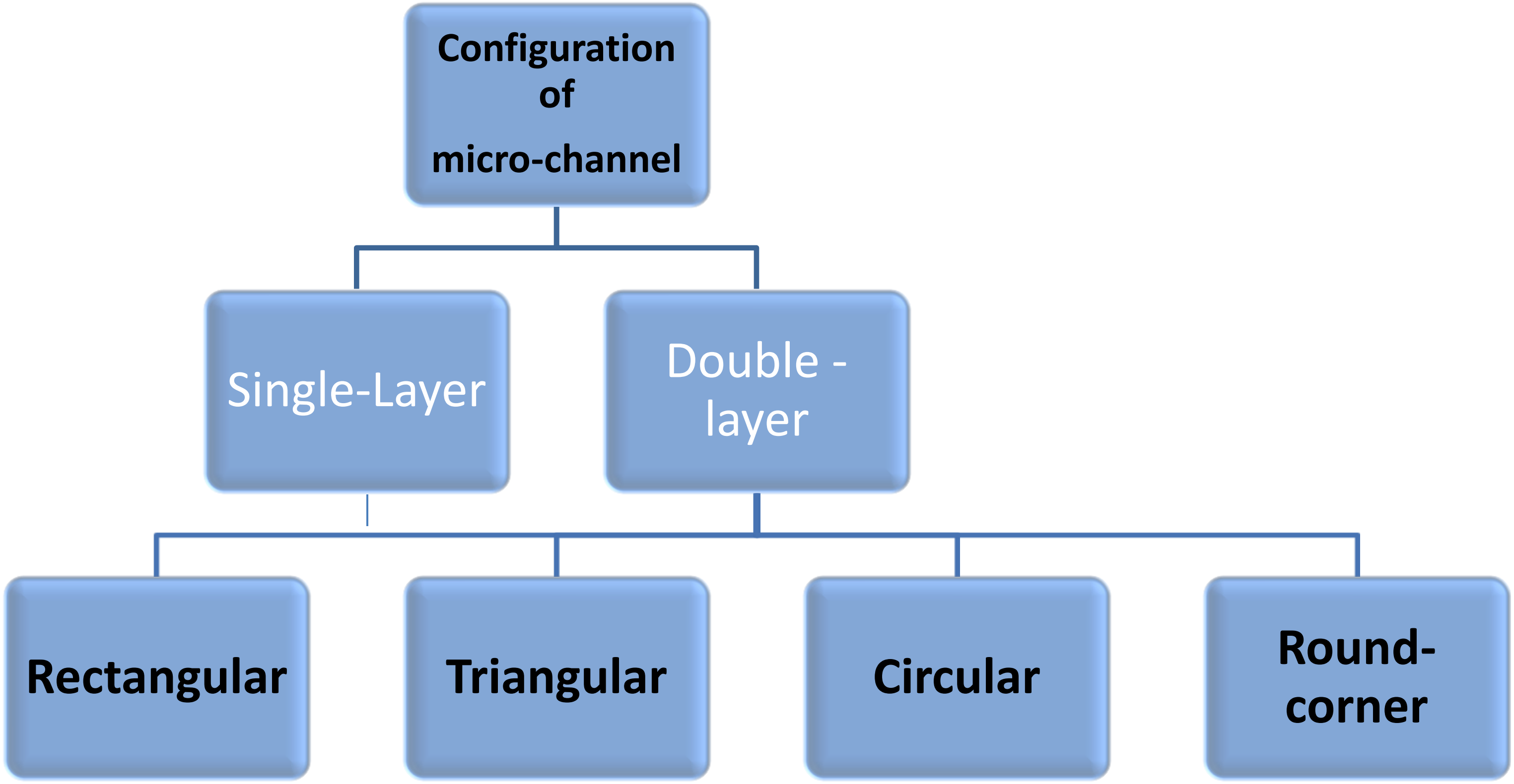
Microchip cooling techniques

INTRODUCTION

Definition of micro-channel

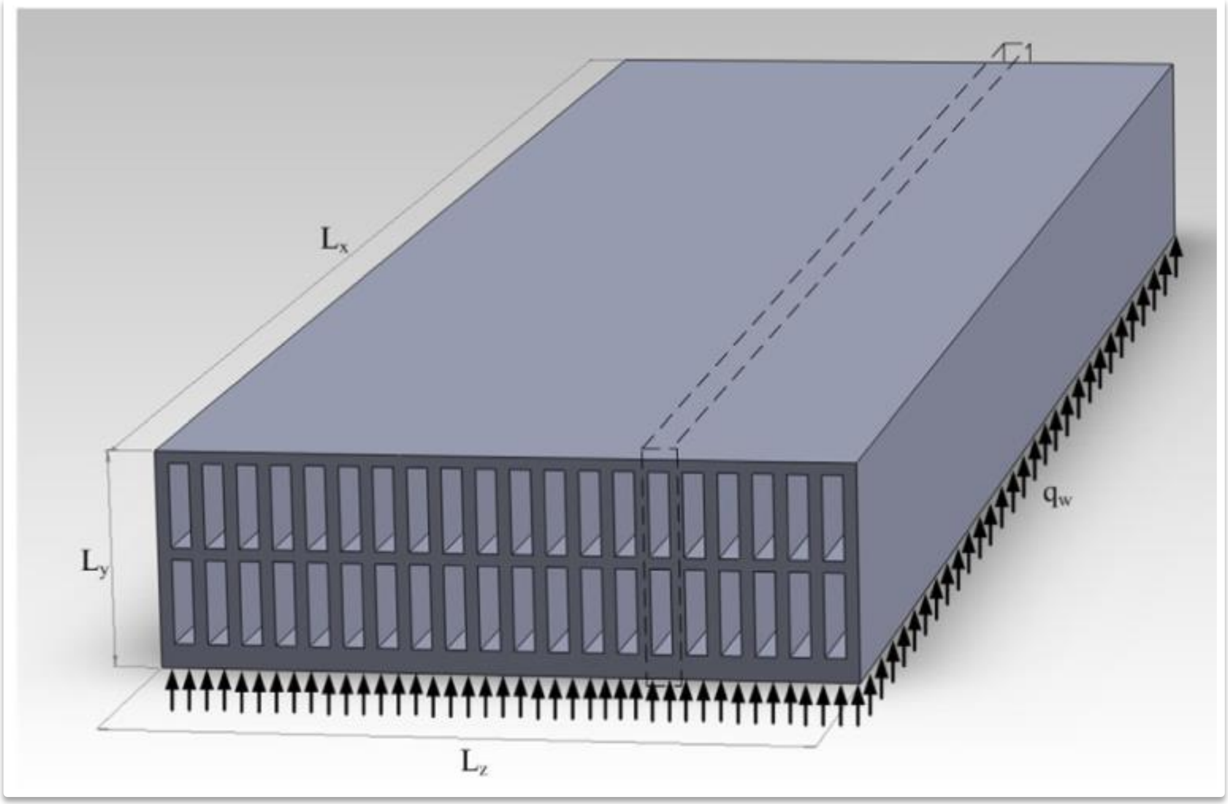
Author	Parameter	Range
Mehendale and Jacobi (2000)	Hydraulic diameter	1 – 100 μm
Kandlikar et al. (2001)	Hydraulic diameter	50 – 600 μm
Kew and Cornwell (1997)	Confinement number	≥ 0.5

INTRODUCTION



INTRODUCTION

Double-layer micro-channel



- Invented by Vafai and Zhu (1997)
- Provide more coolant in the upper layer
- More uniform surface temperature distribution
- Absence of flow boiling in DL-MCHS

K. Vafai, L. Zhu, Analysis of two-layered micro-channel heat sink concept in electronic cooling, International Journal of Heat and Mass Transfer, vol. 42, pp. 2287-2297, 1999.

INTRODUCTION

At the experimental and manufacturing level, few studies concentrated on DL-MCHS fabrication specially the metallic-based one. One potential reason behind a remarkable few experimental studies of DL-MC is the difficulty in fabrication

S. S. Bertsch, E.A. Groll, S.V. Garimella, Effect of heat flux, mass flux, vapor quality, and saturation temperature on flow boiling heat transfer in microchannels, Int. J. of Multiphase Flow, vol. 35 (2009) pp. 142-154.

INTRODUCTION

Fabrication processes can be grouped into two groups

1-Conventional process : is an extend to the macro-manufacturing concept like computer numerical controlled (CNC) machining ,

2-Non-conventional process that depend on chemical reactions such as X-ray lithography, deep reactive ion etching, deep UV lithography, electrical discharge machining (EDM) and laser machining

Hear transfer coefficient

Increases after ONB

Decreases after CHF

Y. Wang, K. Sefiane, Effects of heat flux, vapour quality, channel hydraulic diameter on flow boiling heat transfer in variable aspect ratio micro-channels using transparent heating, Int. J. of Heat and Mass Transfer , vol. 55 (2012), pp.2235-2243.

Methodology

Conventional (tool-based) micro-machining has advantages over a lithography technology in terms of cost effectiveness, efficiency and productivity

Moreover, different fabrication techniques produce specific geometrical shapes (rectangular, triangular, rounded-corner and ect.) those influence the overall thermal performance and pressure drop.

EDM-wire cut technology and End-mill machining are the only two available methods to manufacture microchannel with given dimensions and chosen material

Methodology

wire-cut EDM and low speed Micro End-Mill processes are needed to be addressed for DL-MC machining in two main domains:

(1) geometry variation and

(2) surface integrity and burr formation

MATHEMATICAL MODELING

Machines

Multi-Purpose Miniature Machine

Wire cut EDM machine

Surface roughness measuring machine (WYK) is utilized to measure the value of surface roughness Ra

Micro-tool and micro-channel substrate material

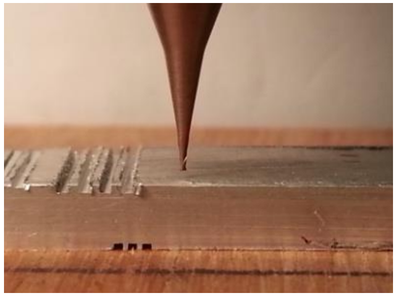


Fig 2: Different micro-diameter end mill

Machining conditions

Table 1 : Machining condition in micro End-Mill machine:

Cutting speed	spindle speed	width of cut (tool diameter)	depth of cut
0.5 mm/min	1000 rpm	200 µm	100 µm
1 mm /min	1500 rpm	300 µm	200 µm
2 mm /min	2000 rpm	400 µm	300 µm
3 mm /min	2500 rpm	500 µm	400 µm
4 mm /min	3000 rpm		500 µm

Table 2:-Machining conditions in EDM wire cut

Rate feed cutting	Wire feed rate speed
2 mm/min	10 mm/s
4 mm/min	12 mm/s
6 mm/min	14mm/s
8 mm/min	
10 mm/min	
12 mm/min	
14 mm/min	

RESULTS, Burr formation

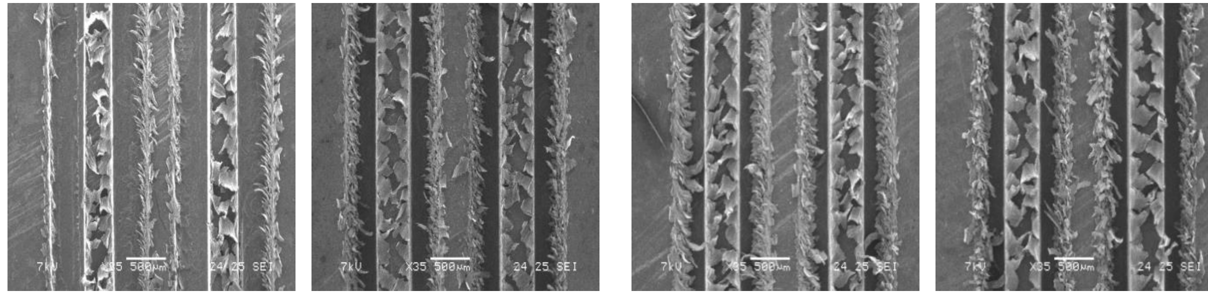


fig3.a:From lift , top burr formation for (0.5, 1,2 and 3 mm/min) cutting speed at at 3000 rpm and 400 µm tool diameter

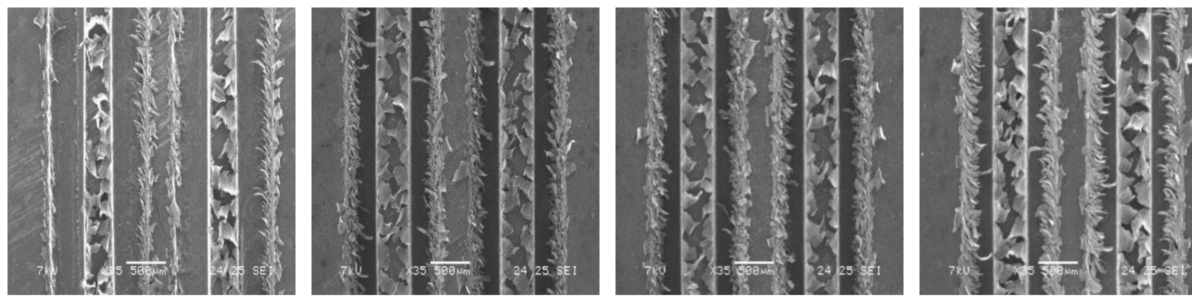
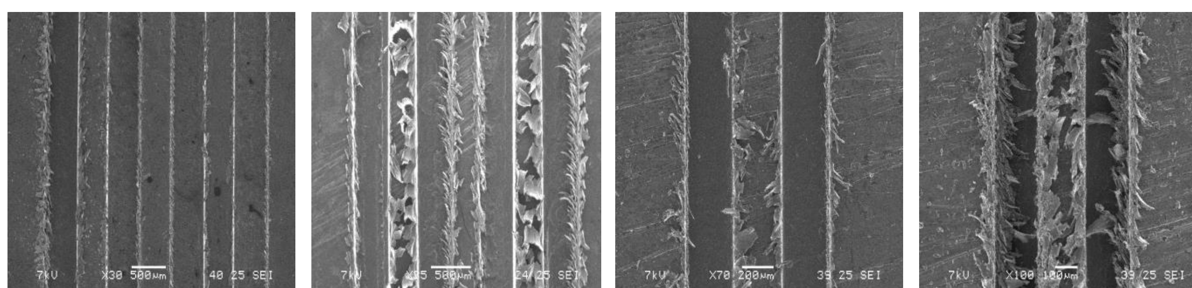


Fig 3.b: From lift, top burr formation for (3000, 2500, 2000 and 1500 rpm) spindle speed at 1 mm/min speed and 400 µm tool diameter.

Fig 3.b : From lift , top burr formation for (500,400,300 and 200 µm) tool diameter at 1 mm/min cutting speed and 3000 µm spindle speed



RESULTS, Burr formation

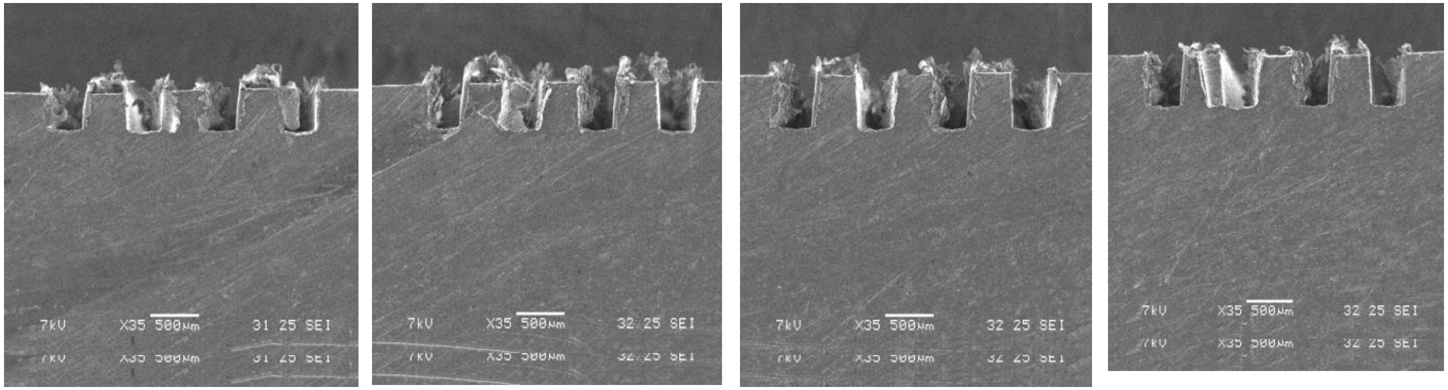
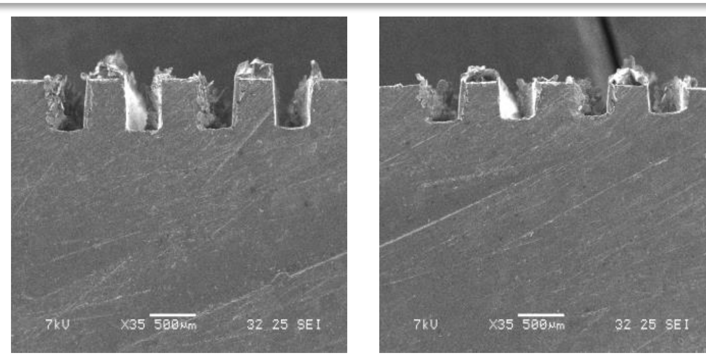


Fig 4.a From lift, entrance burr formation for (0.5, 1,2 and 3 mm/min) cutting speed at 3000 rpm and 400 µm tool diameter



From lift, top burr formation for (3000 and 2000 rpm) spindle speed at 1 mm/min speed and 400 µm tool diameter.

RESULTS

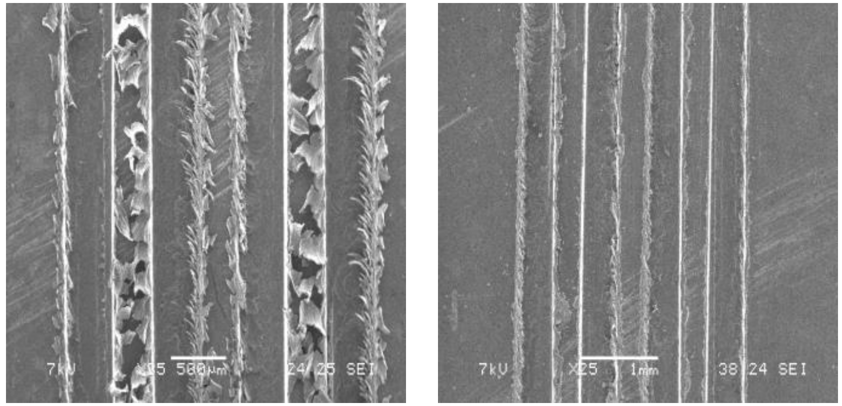


Fig 5: Microchannel sample before and after cleaning using tradition sand paper.

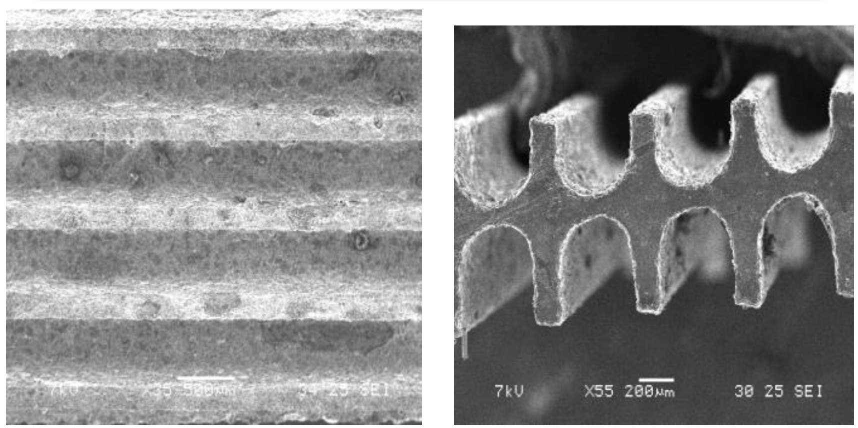


Fig 6. Top and side view of DL-MC fabricated by wire-cut EDM

Surface integrity

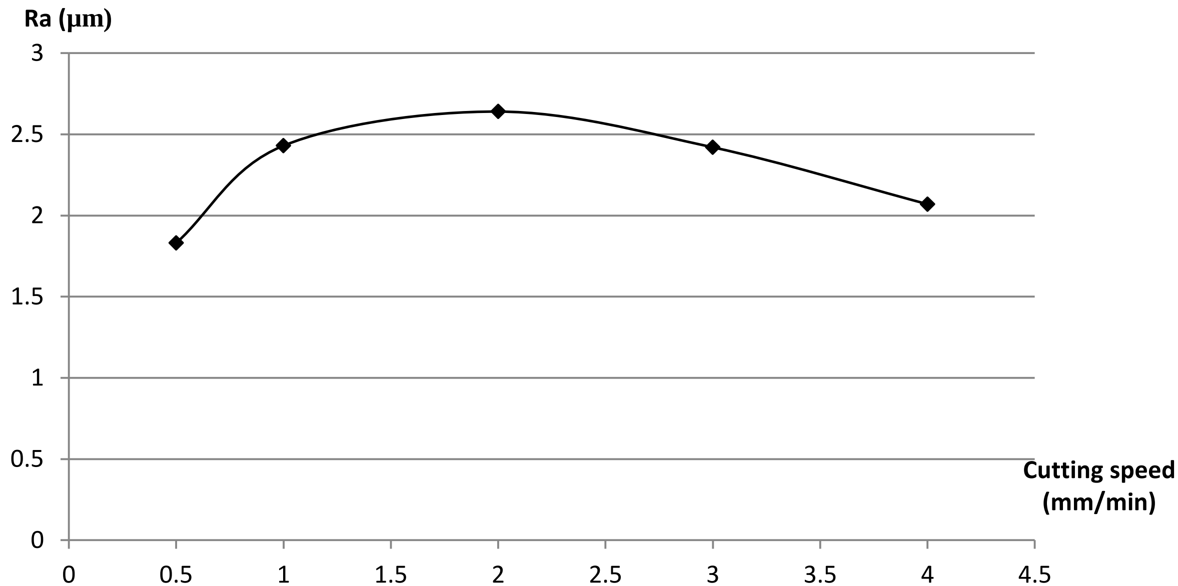


Figure 7.a : Ra with Cutting speed variation

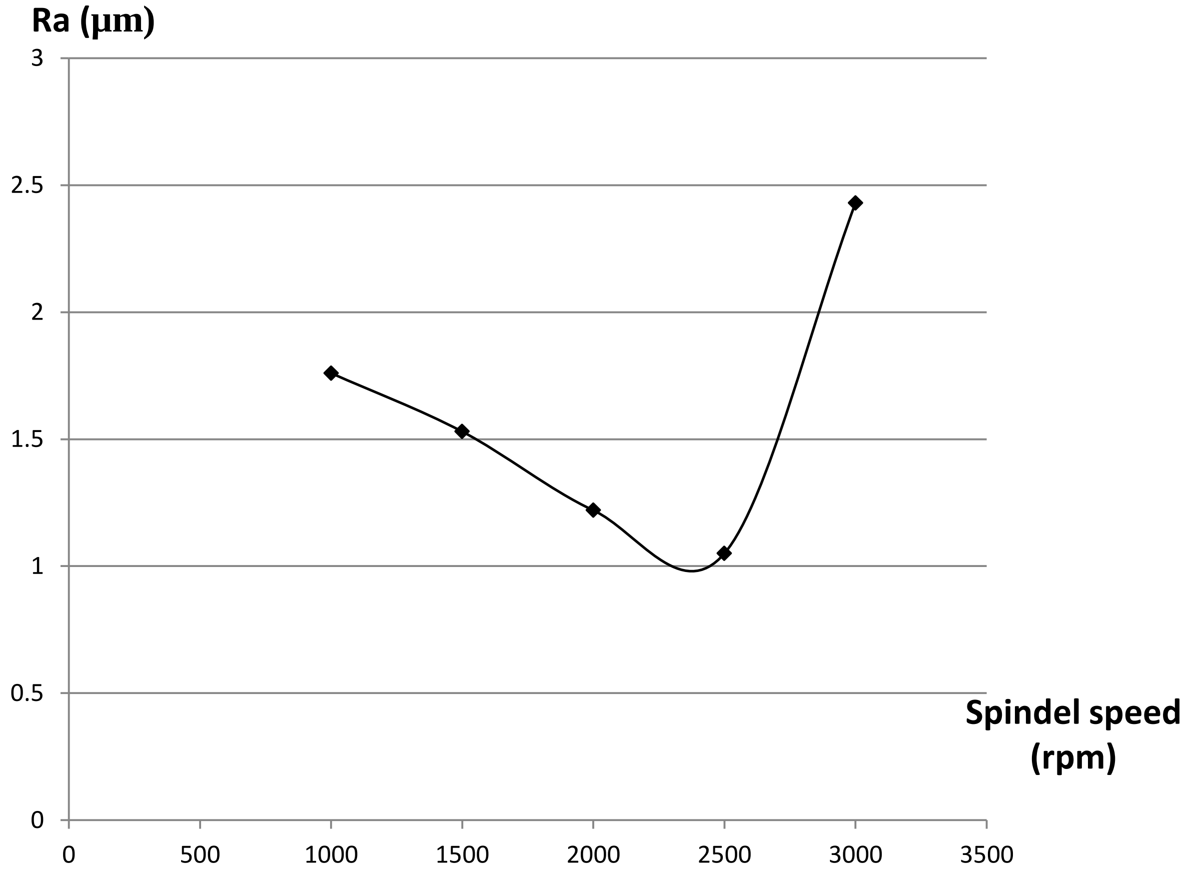


Fig 7.b Ra with spindle speed variation

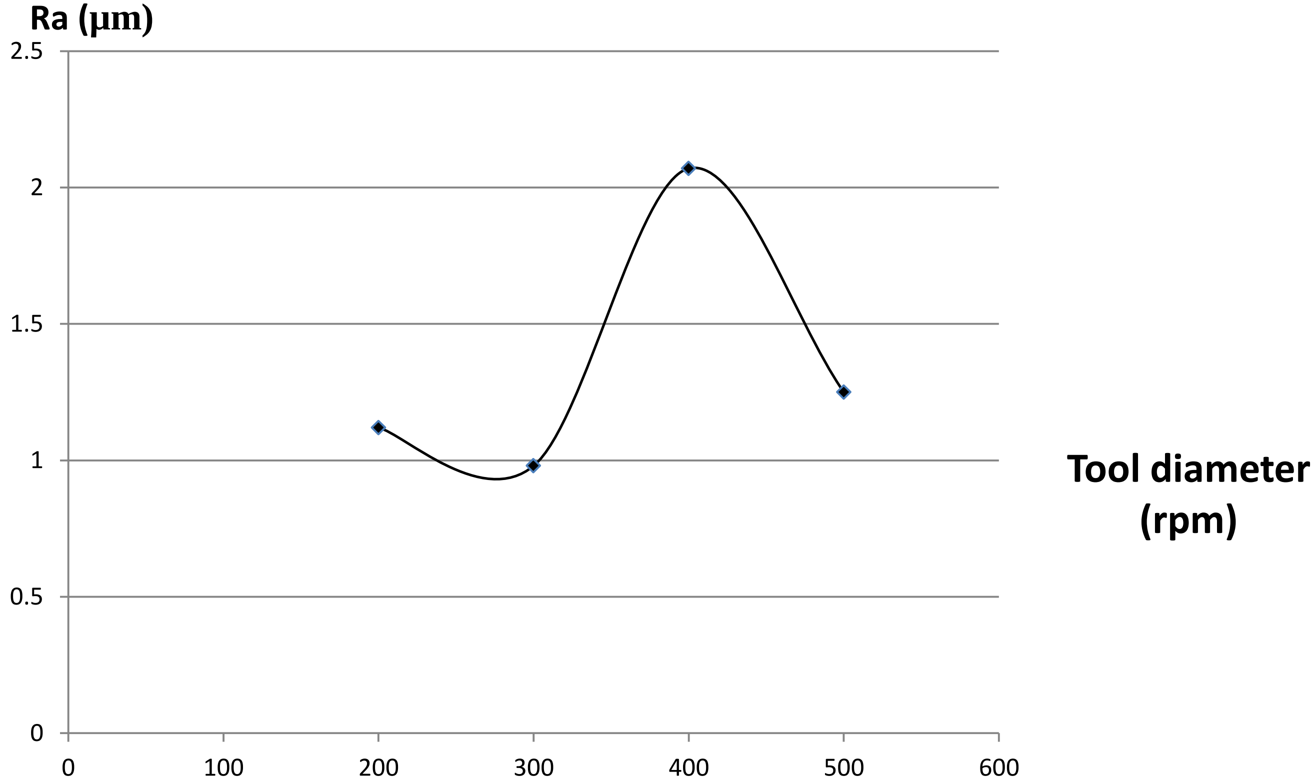


Fig 7.c Ra with tool diameter variation

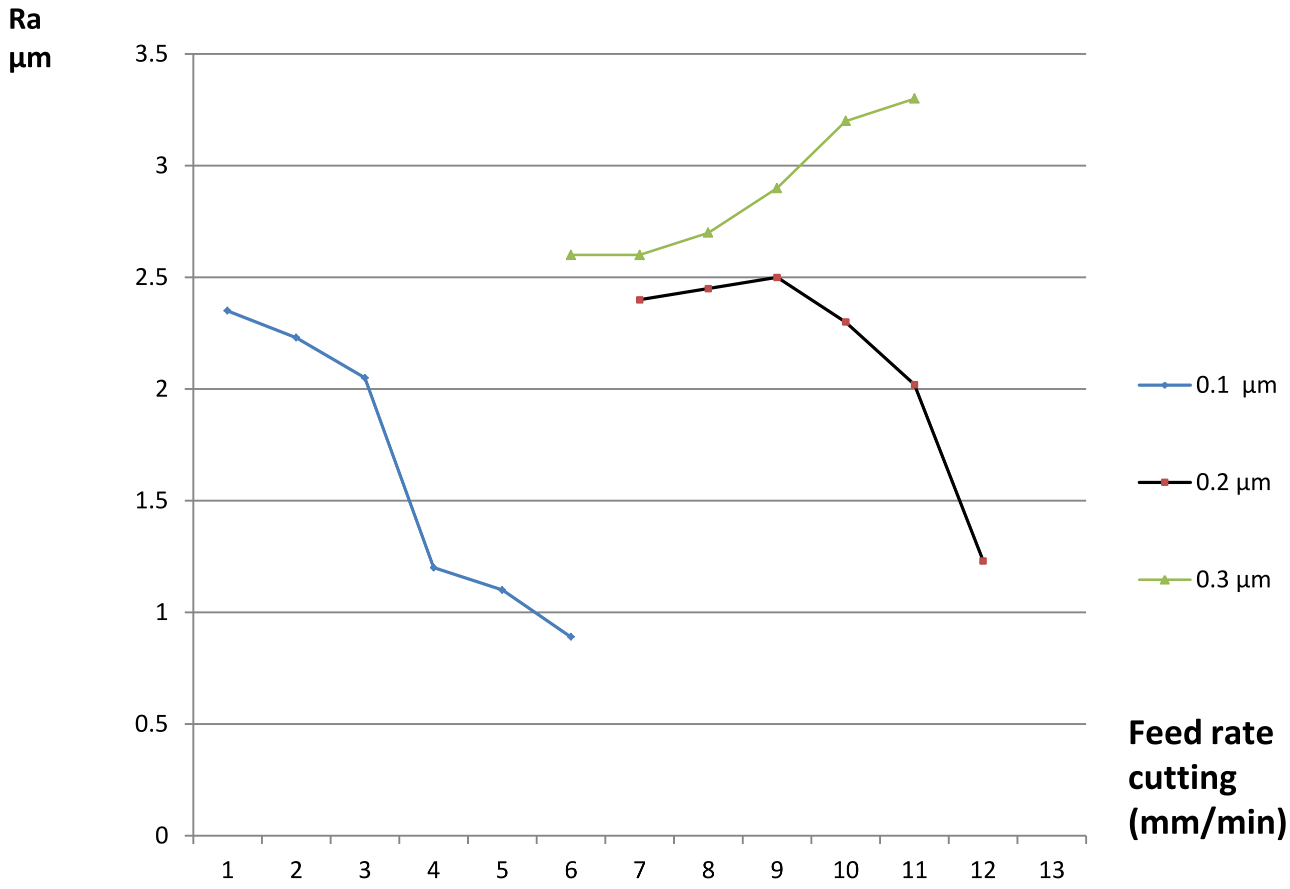
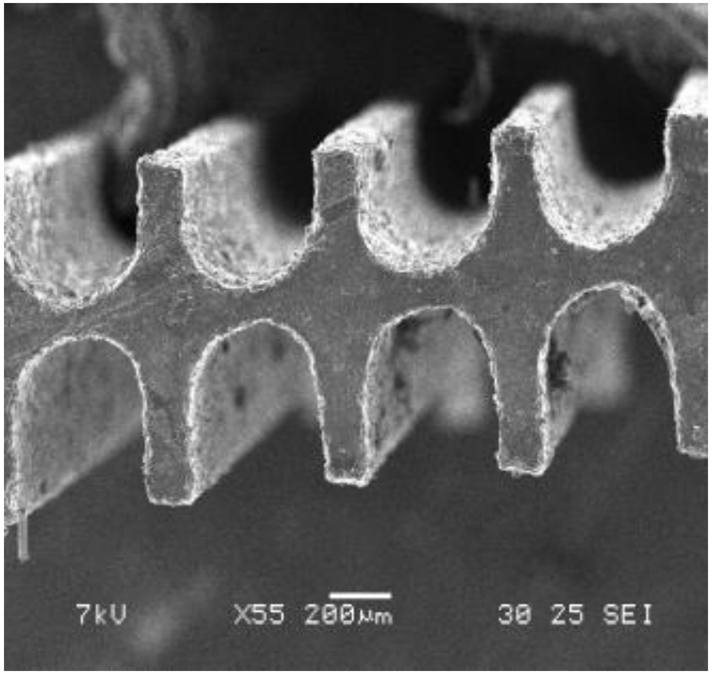
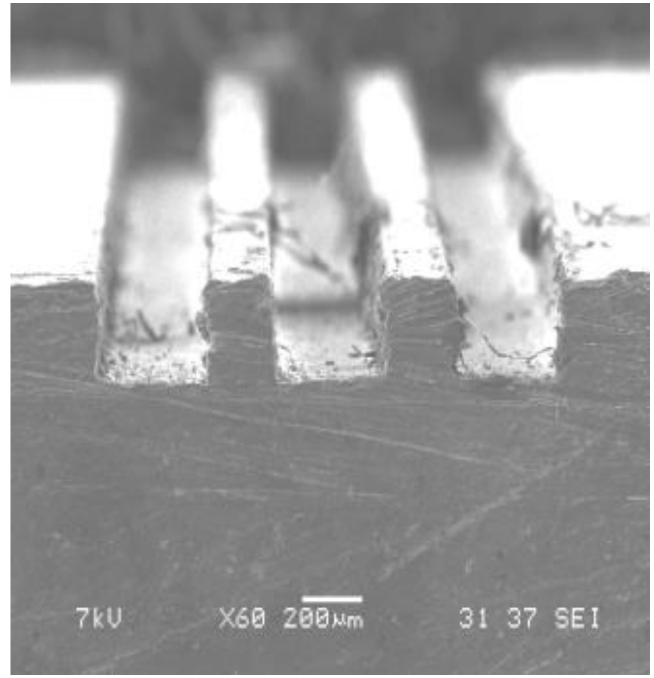


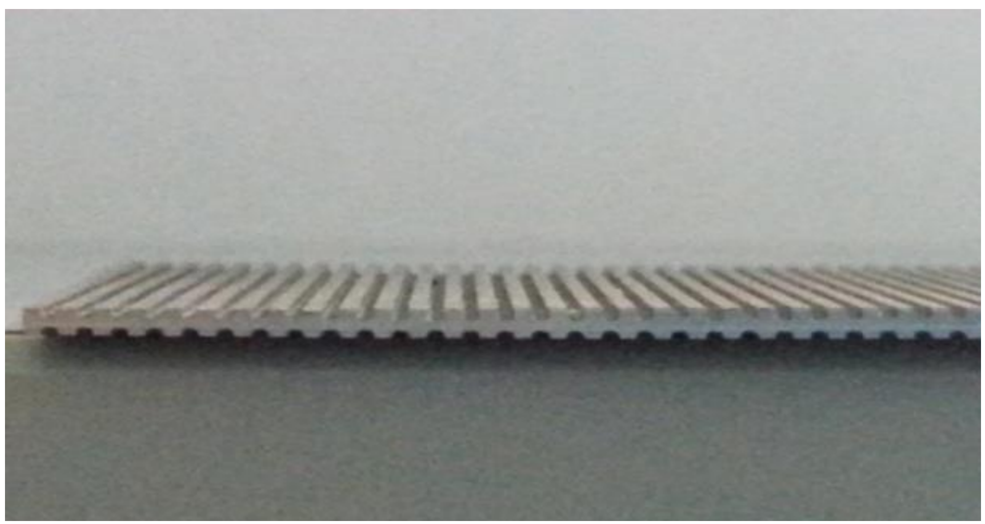
Fig. 8 measured surface roughness Ra for wire-cut EDM process as a function of feed rate cutting and wire diameter .



Rounded corners shape



Rectangular shape



Double layer microchannel

Conclusion

- Both EDM wire cut and micro End mill can produce microchannel heat sink

- Careful consideration should be taken for the speed of the tools and wire cut.


THANK YOU