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A Photochemical Machining-Based Experimental Investigation of Nickel Silver Etching Depth

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Abstract: The technique known as photochemical machining (PCM) uses etchants and a photoresist to corrosively machine away specific regions of sheet metal components. It is among the most significant and least well-known unconventional processes. The production of geometrically complicated machine components from engineering materials that cannot be cheaply or practically shaped by traditional machining procedures has made considerable use of unconventional machining techniques. The parametric optimization of steel photochemical machining (PCM) is the main topic of this research. Etching temperature and etching time have been chosen as the control parameters. Ferric chloride has been used as an etchant in PCM. Surface roughness and edge deviation should be minimal, while etching depth is desired high. The purpose of the study is to investigate the effect of control parameters on response measures, that is, surface roughness, etching depth and evaluating different weight percentage for each performance measure.
Keywords: Photo Chemical Machining, Photo tool, etching, Varying etching parameters, overall evaluation criteria.

I. INTRODUCTION

There are numerous names for the technique of photochemical machining, such as chemical milling, photochemical etching, photochemical machining, photochemical etching, and even the acronym "PCM." These names all refer to the same procedure. These days, the PCM sector is essential to the manufacturing of many precision parts, including copper printed circuit boards, silicon integrated circuits, micro fluidic channels, and decorative objects. The next paragraphs provide an explanation of the work done by previous authors on photochemical machining. Kapp-Schwoerer, Diehard, et al. The impact of liquid-type photoresist for photochemical machining was described in [1]. Several types of photoresists will be discussed in this article, with a particular emphasis on liquid photoimageable etch resists for creating decorative or useful metal components. The PCM roadmap, examples, and the state of the art were provided by David, M. Allen et al. [2]. This study looks at recently produced PCM goods that are particularly pertinent to micro engineering, micro fluidics, and microsystem technology. It also looks at the economic elements of these products and the present issues that need to be researched in the PCM business. The chemical compositions or constituents and photochemical mechanics of photoresist materials were the main topics of Andrew, R. Barron et al. [3]. It is explained how the composition of photoresists of the positive and negative types reacts to ultraviolet light. Additionally, a comparison of negative and positive photoresist is provided. Wangikar, S.S. [4] explored parametric optimization for photochemical machining PCM of brass and German silver. A two-dimensional etching simulation model was created, and the effects of process parameters on micro-geometry were experimentally examined. Photographic and chemical etching techniques are used in PCM, one of the popular non-traditional machining processes. The first step in the procedure is printing the part's shape onto photographic film that is both dimensionally stable and optically clear. The procedure begins with the creation of the necessary design, known as the photo tool, in AutoCAD software, which is then printed on a transparent plastic sheet for etching. Misal, N.D. [5] He covered the implications of these parameters on surface topology as well as how to estimate the ideal machining parameters needed for photochemical machining of Inconel 718. Ferric chloride ($FeCl_3$) was used as an etchant in an experimental analysis to determine the ideal parameter values. Etchant temperature, etching duration, and concentration are the parameters taken into account in this analysis. Both surface topology and etching performance increased, according to the experimental analysis.

The major steps involved on PCM is given below

1) Preparation of photo tool
2) Selection of base metal
3) Preparation of workpiece
4) Photoresist coating
5) Developing

6) Etching
7) Stripping and inspection

According to Misal, N.D. [6], exposing samples more or less can result in a deeper PCM. The more light that is passed through the picture tool, the less intense the light will be. A transparent piece of paper is used to print many images to create the photo tool. The photo tool is being illuminated. Depending on the features of the picture tool, different light sources emit varied amounts of light. In his work, Saraf A.R. [7] showed that the energy concentration of light varies with color, causing photoresist material to harden less and more. The development of photoresist material is the primary determinant of the etching process. Etching decreases with less developing and increases with more developing. According to a study by Kamble, B. et al. [8], PCM has been used extensively over the past 40 years in the electronics, precision engineering, and decorative industries to manufacture thin, flat, and complex metal parts (such as lead frames, color TV masks, sensors, heat plates, and printed circuit boards). These days, the PCM industry is crucial to the development of copper printed circuit boards, microfluidic channels, microfilters, and other precision parts and ornamental elements. In order to optimize the PCM process parameters in etching while taking into account a number of output parameters, Misal, N. D. [9] used the grey-based Taguchi approach. Grey relational analysis is used in this innovative method to solve the PCM process. The performance characteristic is a gray relation grade derived from the grey relational analysis. The parameter design suggested by the experiment's design is used to identify the ideal process parameter. A.A. Utpat. [10] gave the study of depth of etching in PCM by varying temperature and time of etching. The objective was to study the effect of these parameters and find relation between them. Sapkal A.D.[11] focused on optimum condition for etching of Brass material using PCM by OEC Analysis.

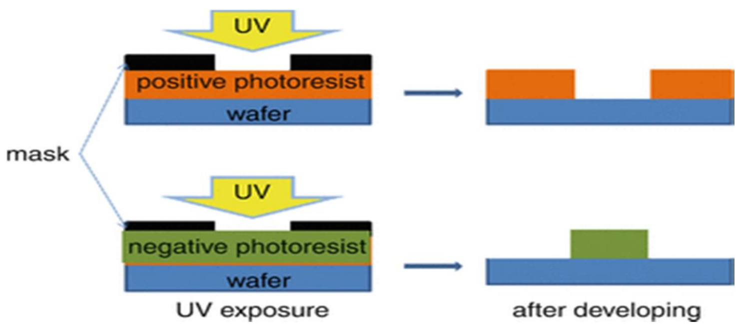

Fig.1 Types of photoresist

II. METHODOLOGY

A. Material Selection

The material used for this study is a Nickel Silver, because it is more harden than copper and Aluminum and have to study on machining parameters of Nickel Silver. The size of specimen used is 20mm x20 mm x 0.5mm (W×L×T). PCM was carried out for flat surfaces of Nickel Silver.$Fecl_3$ is used as etchant and negative photoresist for experiments.

B. Experimental procedure

Creating Photo tool

Photochemical machining process is carried out by using a photo tool. The photo tool is an AutoCAD drawing with detailed dimensions of the required shape which is then printed on a tress paper or transparent paper

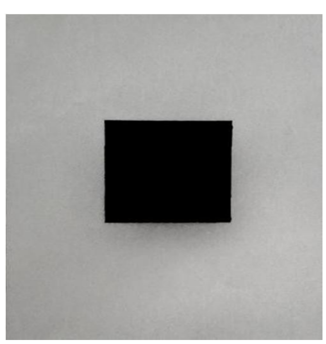
Fig.2 Photo tool in AutoCAD

C. Preparation of Workpiece

After preparing the photo tool the Nickel Silver material is cut into required size. The first task is to clean the workpiece. The cleaning of the surface is done firstly by polishing the surface with a sand paper and then cleaning it by thinner (trichloroethylene or acetone). This step is done to make the surface of workpiece free from foreign particles, debris, dust, grease, oil and other contaminants. Because of polishing and cleaning with thinner it gets easier to have a good adhesion of photoresist with the metal surface

D. Coating of Workpiece

After cleaning the workpiece, a thin layer of photoresist is applied on the metal surface. The negative type photo resist was used for experimentation. The characteristic of negative photoresist is it get harden when UV light is incident on it. The properties of negative photoresist for different colors is different, it depends on the energy content of light coming out from colored photo tool.

Fig.3 Photoresist and Developing Solution

E. UV Exposure.

In PCM, it is necessary to expose material (base metal) in all directions, the etching can be takes place in all directions. The Exposure machine is designed in such a way that in can expose the specimen in all direction. The 1 KW power UV light bulb is used for exposing the sample. It radiates the intensity 1800 microwatt per centimeter square at 25 cm distance. In traditional machining process the samples are exposed in only one direction i.e. in 2D PCM, this is the main difference in 2D and 3D exposing machine.

Fig.4 3D Exposure machine

F. Development Phase

The developing solution is the mixture of sodium carbonate and water. After UV exposure the specimen is held in the developer for 90 seconds, which results in the formation of impression on workpiece. After that specimen is washed with water. The developing of photoresist is different for different colors. photoresist development relates with the etching process.

G. Etching.

The final step of the machining is to put the developed metal workpiece into the etchant. The etchant is the solution of $FeCl_3$ and water. In etching of the component can be done by late etching process. In conventional etching process the photo tool is black and white, in which only etching of black color is happen and there is no effect on white color. The photoresist thickness is varying with color.

III. EXPERIMENTAL ANALYSIS

The numbers of experiment are carried out to analyze etching behavior of Nickel Silver material by the input parameters are etching time, temperature etc. and response parameters are etching depth and surface roughness. Other parameters like photoresist thickness, exposing time and developing time are kept constant throughout the experiments. The design matrix for performing experimentation along with recorded response parameters for Nickel Silver is given in Table 1. After machining, Ra has been measured using a Mitutoyo surface roughness tester. The depth of etch has been measured using the digital micrometer. For satisfying this multi-objective condition, overall evaluation criteria (OEC) have been used by assigning different and equal weight percentage to response measures. Surface roughness is a constituent of surface texture. The surface roughness of each specimen of steel was recorded at three locations, and the average value is taken for analysis.

Table 1. Observation values for Nickel Silver Material.

Temperature (°C)	Time (Min)	Etching depth (mm).	Roughness (µm)
40	10	0.03	0.157
	20	0.1	0.528
	30	0.13	1.22
50	10	0.1	1.056
	20	0.23	1.169
	30	0.37	1.388
60	10	0.33	1.332
	20	0.47	1.528
	30	0.53	1.780

IV. RESULT AND DISCUSSION

The performance of photochemical machining of Nickel Silver has been evaluated by surface roughness and etching depth. The experimental data analysis has been carried out for determining the effect of temperature and time on Ra and etching depth. The average effect of temperature and etching time on etching depth for Nickel Silver is shown in fig 5, fig 6 and fig 7 whereas effect on surface roughness is shown in fig 8, fig 9 and fig 10. It has been observed that Lowest value of etching depth is observed at 40°C temp and 10 min time whereas highest value is observed at 60°C temp and 30 min time.

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A. Effect of Temperature and Etching Time on Etching Depth

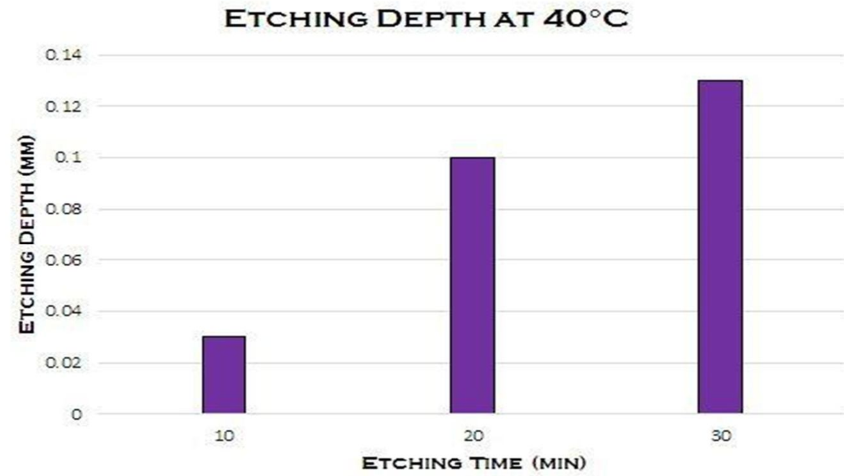


Fig.5 Etching depth at 40 °C

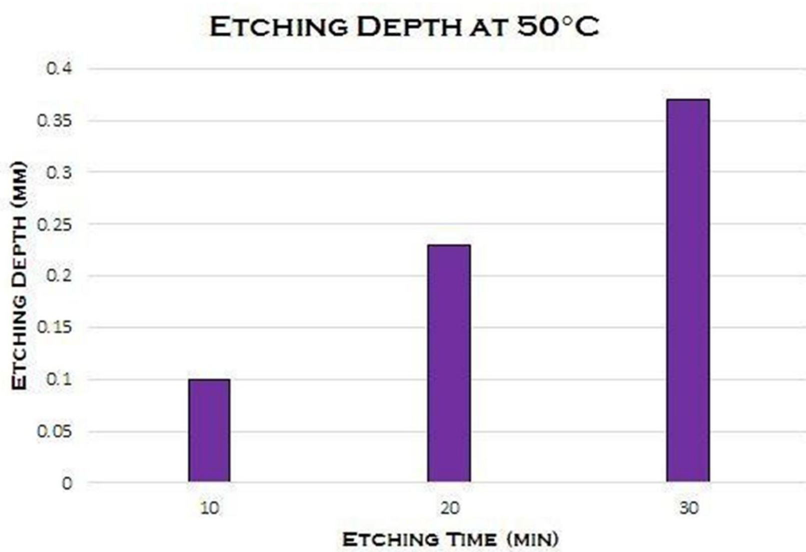


Fig.6 Etching depth at 50 °C

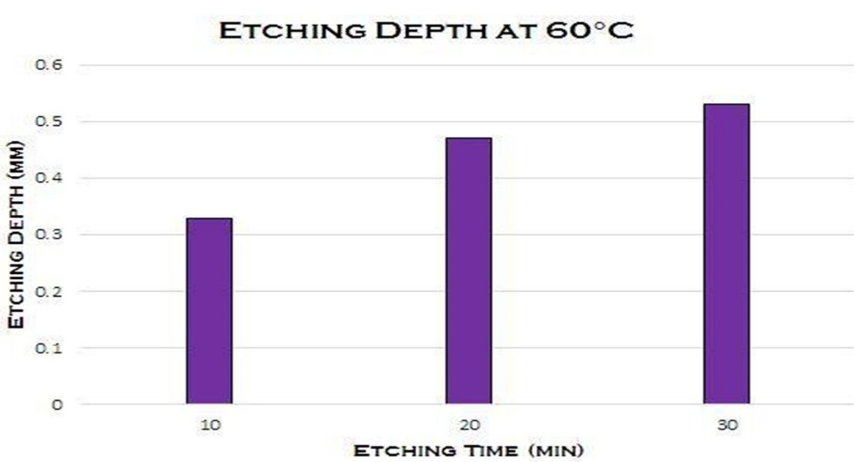


Fig.7 Etching depth at 60 °C

B. Effect of Temperature and Etching Time on Surface Roughness

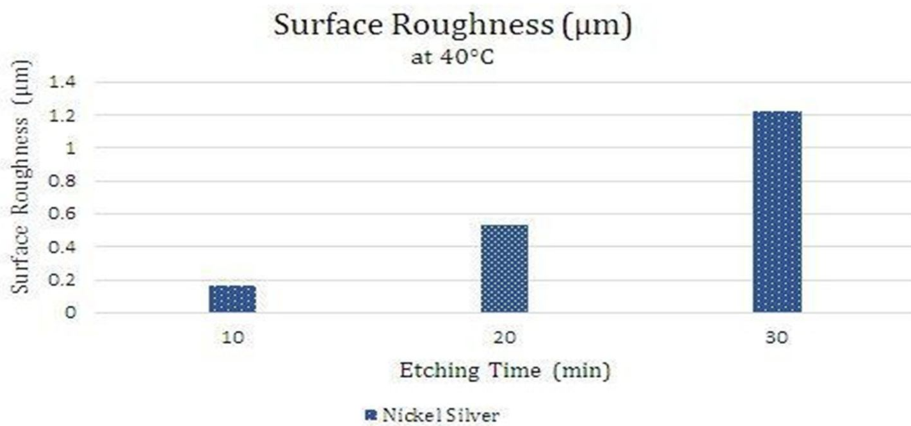


Fig:- 8 Effect of temp and time on Surface Roughness at 40 °C

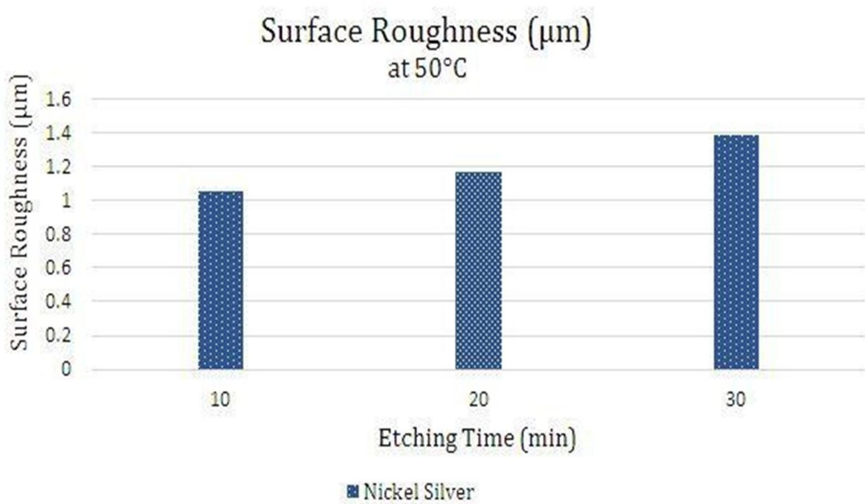


Fig:- 9 Effect of temp and time on Surface Roughness at 50 °C

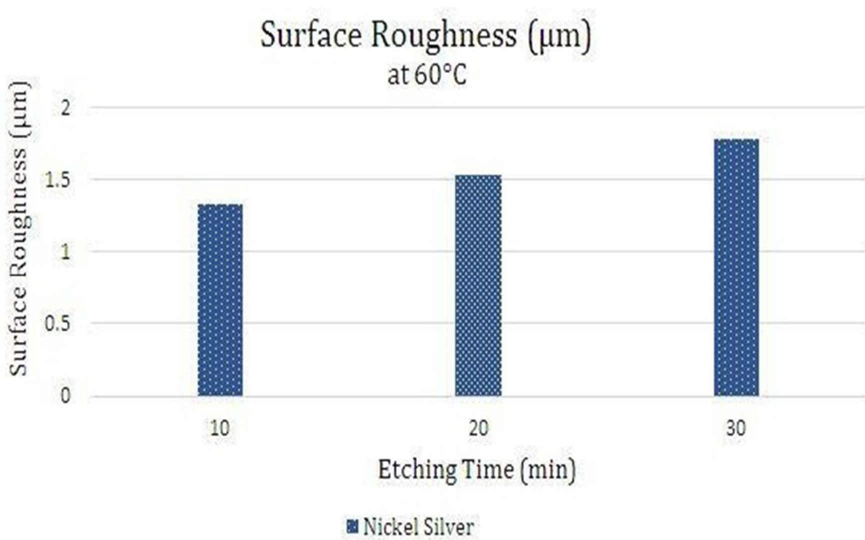


Fig:- 10 Effect of temp and time on Surface Roughness at 60 °C

V. CONCLUSION

To find the relation between temperature, time and etching depth experimental analysis was carried out, general reaction mechanism is developed for photoresist and developer solution. The etching depth is measured for Nickel Silver material. The experimentation is carried out to find out the depth of etching for Nickel Silver materials using FeCl3 etchant.

From above observation conclusions are given below:

1) It is observed that the etching depth is depend upon etching temperature and time.
2) The depth of etch is going to increase by increasing temperature and etching time.
3) The Surface Roughness value is going to increase by increasing temperature and etching time.
4) The Etching depth of Nickel Silver material goes on increasing with change in temperature and time.

REFERENCES

[1] Diethar Kapp-Schwoerer, Dr. Kurt Meiser, Charles Gantner. (1997). Liquid Resist for Photo Chemical Machining. (HTP Hi Tech Photopolymer AG, Basel, Switzerland).

[2] Allen, D. M. (2004). Photochemical machining: from „manufacturing's best kept secret ‟to a $6 billion per annum, rapid manufacturing process. CIRP annals, 53(2), 559-572.

[3] Barron, A. R. (2009). Composition and Photochemical Mechanisms of Photoresists. Creative Commons, 1, 1-7.

[4] Wangikar S.S., Patowari P.P. and Misra, R.D. “Parametric Optimization for Photochemical Machining of Copper Using Grey Relational Method”, In Techno-Societal 2016, International Conference on Advanced Technologies for Societal Application, pp. 933-943, 2016.

[5] Misal N.D. and Sadaiah M. “Investigation on Surface Roughness of Inconel 718 in Photo chemical Machining”, Advances in Materials Science and Engineering, 2017.

[6] Misal N.D., Saraf, A.R.and Sadaiah M. “Experimental investigation of surface topography in photo chemical machining of Inconel 718”, Materials and Manufacturing Processes, vol. 32, no. 15, pp.1756-1763, 2017.

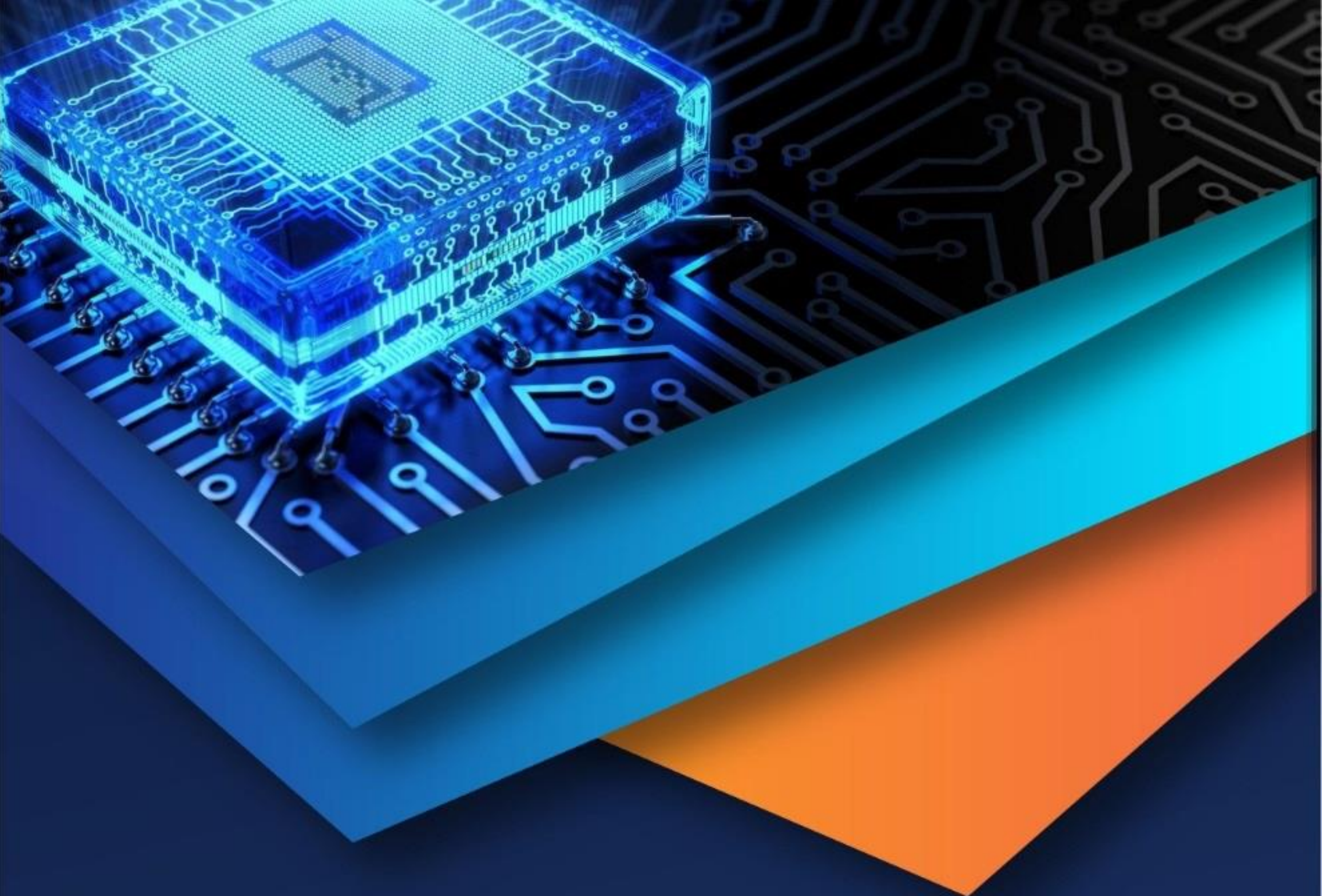
[7] Saraf A.R., Misal N.D. and Sadaiah, M. “Mathematical modelling and optimization of photo chemical machining”. In Advanced Materials Research, Vol. 548, pp. 617-622, 2012

[8] Kamble, B., Utpat, A.A., Misal, N.D. and Ronge, B.P., 3D Photochemical Machining of Copper By using Colored Photo tools.

[9] Misal, N. D., & Sadaiah, M. (2018). Multi-objective optimization of photochemical machining of Inconel 601 using grey relational analysis. Materials Today: Proceedings, 5(2), 5591- 5600.

[10] Jadhav Saurabh M., Karatkar Onkar V., Bangale Kamesh N., Choudhari Deepak B., Utpat A.A., Kamble Banduraj K. (2019) Etching Depth variation of Brass Material for Different Operating Condition

[11] Sapkal, A. D., A. A. Utpat & Kamble B (2020). An Experimental Investigation of Etching Depth for Photochemical Machining of Brass.



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