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Comparative Study of $FeCl_3$ and $CuCl_2$ on Geometrical Features Using Photochemical Machining of Monel 400

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Abstract

In this study, Monel 400 was machined using etchants, like ferric chloride ($FeCl_3$) and cupric chloride ($CuCl_2$) at different temperatures, concentration and type of geometry (viz. circular, hexagonal, square, rectangular and triangular). The study focuses on the comparative impact of input process parameters in perspective of depth of etch, undercut, and weight loss. Comparative study of $FeCl_3$ and $CuCl_2$ determines that the overall performance is better for ferric chloride etchant. The undercut observed in $FeCl_3$ was more than $CuCl_2$, but the better geometrical accuracy found with $CuCl_2$ etchant solution. Type of geometries responsible for the depth of etch and weight loss. Triangular geometry shows higher weight loss and depth of etch. Higher weight loss and depth of etch is observed with $FeCl_3$ than $CuCl_2$ etchant. The weight loss and depth of etch increases from 0.0504 g to 0.0737 g and 0.0436 µm to 0.1547 µm respectively for $FeCl_3$ for circular, hexagonal, square, rectangular and triangular shapes. Similarly, for $CuCl_2$ these values are 0.0386 g to 0.0686 g and 0.0236 µm to 0.117 µm respectively.

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Keywords: Ferric chloride ($FeCl_3$); cupric chloride ($CuCl_2$); Monel 400; geometrical features; weight loss, photochemical machining

1. Introduction

Etching is the process of uses strong acid to etch the parts of a metal surface to create a intricate designs in the metal. Etching / (PCM) process can be differentiate by etch rate, selectivity, reproducibility, uniformity directionality, and surface quality. Etching process comprises three basic actions, 1) Movement of the etchant to the surface to be etched, 2) Chemical reaction to form a compound that is soluble in the surrounding medium and 3) movement of the by-products away from the etched region, allowing fresh etchant to reach the surface. Etching process has different names primarily because it has developed in different parts of the world. Photo etching, photochemical milling, photochemical machining (PCM) and photochemical etching all refer to the same process [1].

PCM is a material removal process that utilizes UV light and chemical solution as tool rather than customary machine tools. With this procedure, microphotography and photoresist are utilized for characterizing ranges to be cut. PCM offers various crucial points over customary machining strategies for manufacture of a few sections viz. more intricate designs and better definition are feasible, closure tolerance parts can be fabricate under controlled conditions. Tooling expenses can be generously lessened, tool changes require the moderately minor cost of making new photographic tool instead of new tool and parts can be

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created speedier than some other customary processes. The metallurgical properties and subsequently mechanical properties of a metal are unaffected [2].

Monel 400 was chosen as a specimen for the present study. Monel 400 is a super alloy, has superior mechanical and thermal stability than SS 304 steel and can withstand a wide variety of severe operating conditions, such as corrosive environments and high stress [3]. Monel 400 also exhibits resistance to cavitation erosion. It can work in all types of atmospheres, including nuclear fuel reprocessing reactors. Monel 400 works excellently where re-boiling conditions exist and is best suited for heat exchanger applications [4, 5]. Monel 400 has less than one-half the erosion rate of nickel in industrial atmospheres, which found extensive commercial use [6].
Numerous work have been described over corrosion of Monel. It has been observed that the study of chemical machining on Monel 400 still in fed light. Few author studied the effect of etching process parameters on Monel [7, 8]. Selection of effective etchant for any material is the most significant factor. The effective etchant would produce lower undercut, higher depth of etch and better geometrical accuracy. It was seen that these studies generally used alkaline based chemical solutions, e.g., alkaline sulphate solution, non-aqueous solvents [9].

The application of ferric chloride ($FeCl_3$) and cupric chloride ($CuCl_2$) has not been compared and investigated. Therefore, this study would deliver significant information in chemical machining of Monel 400 with $FeCl_3$ and $CuCl_2$. This paper presents the study of chemical machining of Monel 400 using different input parameters like concentration, and temperature (Table 2). The effect of input parameters on undercut, depth of etch, and geometrical accuracy have been examined. The significance of this study is the selection of the etchant for desired output with optimized inputs for Monel 400 etching by finding experimental result and discussion of results are corroborated.

2. Experimental procedures

The experiments of chemical machining of Monel 400 were performed using dip etching in beaker. The selected material chemical composition is given in Table 1. The thickness of substrate was 1mm and were cut to the size of 30 mm × 30 mm.

Table 1. Chemical Composition of Monel 400.

Element	C	Fe	Mg	Ni	S	Si	Cu
% wt	0.3	2.5	2.0	63	0.024	0.5	32

The details experimental procedure is explain with the help of Fig. 1. The study based on seven steps: cleaning, photoresist coating, baking (soft and hard), phototool preparation, exposing, developing and etching. The Monel 400 was cleaned using ultrasonic cleaner (Labman make) and acetone to remove the dust particles. Photoresist coating (negative 1020) carried out using single stage spin coating (Spectron-India). The coating was coated on one of the end faces of the sheet. The next step is to soft bake the coated photoresist in a furnace at 100°C for 10 minutes [8]. Soft baking helps to adhere photoresist over substrate. Photo tool was made on a transparency (100 micron thick). The prepared photo tool is shown in Fig. 2. Photo tool image was exposed using an exposure unit. The Coated substrate and photoresist is irradiated by Ultra-Violet (UV) light (wave length 18 mW/cm2). The temperature was kept at 100°C for post exposure baking to avoid erosion of photoresist during development of photo tool for a period of 10 min. The photoresist film was developed using manual immersion method at room temperature to form photoresist pattern. After development of photoresist, the photoresist film was washed with distilled water to wipe off residual developer solution and then dried by filter paper. The developed photoresist pattern was etched in same etchant solution. After etching, the sheets were washed with distilled water. The photoresist was removed and cleaned with acetone. The experimental set-up of dip etching method and fabricated micro array is shown in Fig. 3 and 4.

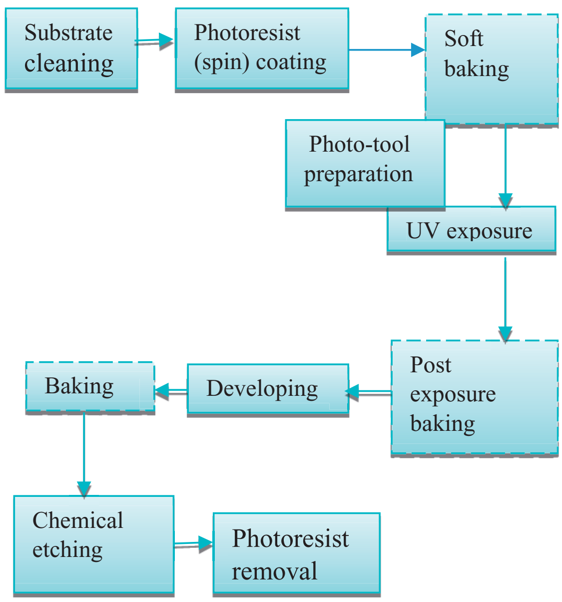

Fig. 1 Experimental procedure of PCM

The selected etching concentration were 300, 400, 500, 600 and 700 g/*l*. The temperature were 40, 50, 60, 70 and 80 ± 2 °C. Single side through etching was carried out and time recorded for each reading combination after each 10 min intervals. The measurement of depth of etch and undercut was carried out by Nikon microscope and TS view software (Tucsen make). Each experiment were repeated three times