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PHOTOCHEMICAL MACHINING OF ENGINEERING MATERIALS

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ABSTRACT

Photochemical machining (PCM) is one of the important nontraditional machining processes in which photographic and chemical etching techniques are employed. The workpiece material is shaped by using a strong chemical solution to dissolve surface of the workpiece that was selectively exposed to machine areas using a photographic technique. The application of photochemical machining has increased extensively in the electronics, precision engineering, medical and decorative industries as well as in the microcomponent production industry. The present study is aimed to provide information on the application of PCM. The selection of etching parameters such as etchants for engineering materials, chemical additives into main etchants and etching temperature on the different machining outputs will be discussed. Also, the influences of environmental legislations on the machining process are examined and the future directions are considered.

Keywords: Photochemical machining, etchants, etching parameters

1. INTRODUCTION

Non-traditional machining processes have extensively been used in the manufacture of geometrically complex machine components from any engineering materials which are not possibly or economically shaped by conventional machining processes. Moreover, these processes have widely been required by increasing demand of microcomponents.

Photochemical machining (PCM) is one of the commonly used nontraditional machining processes in which the photographic and chemical etching techniques are employed. The photographic technique exposes the selected areas to be machined on the photoresist coated workpiece, then the selected areas machined by chemical etchant by chemical etching technique. The process has some advantages such as low tool cost, independent of the physical and mechanical properties of materials and high precision etc. The disadvantages of the process are the workpiece material thickness limitation (up to 2 mm for most of the materials, 6 mm for copper) and environmental compatibility.

PCM is known as etching, photochemical machining, wet etching, photoetching, photochemical milling etc. First application was carried out to produce jewelries from copper in the Ancient Egypt in B.C. 2500. The important development was established by aerospace/aircraft manufacturers around 1950's and electronics industry pushed its limits for major application such as printed circuit board manufacturing and other electronic components [1-3].

The application of PCM has widely been used in the manufacturing of thin, flat and complex metal parts (i.e. lead frames, colour tv masks, sensors, heat plates, printed circuit boards) in electronics, precision engineering and decorative industries in the past thirty years. Its economical advantages has been established over rival processes like wire electro-discharge machining, laser beam machining and stamping. PCM has also been used in the production of microcomponents for the microtechnology recently [1-6].

The aim of the present study has been provided the latest developments in the application of PCM. The background of PCM was given and major studies were reviewed. The selection of etching parameters (etchant concentration, etching temperature and chemical additives into main etchant etc.) and their effects on the various machining outputs such as etch rate and surface roughness is discussed. Also, the influences of environmental legislations on the PCM process were examined and the future directions are considered.

2. PCM PROCESS

The PCM process is a multistage machining process which is illustrated in Fig 1.

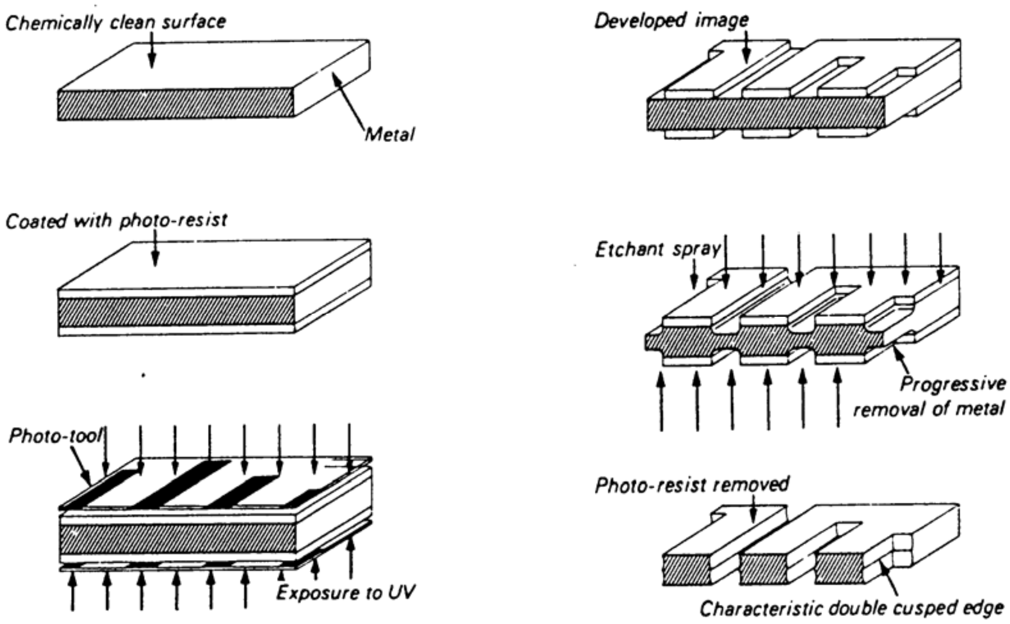

Figure 1. The steps of PCM

First, the material is cleaned to remove the oil, grease, dust, rust or any substance from the surface of material that would provide good adhesion of the photoresist. The most widely used cleaning method is chemical method due to less damages occurred comparing to mechanical cleaning method. Coating with photoresist (dry or wet) is the next stage of PCM. Then the expose of the prepared phototool is carried out with UV light. Developing stage is used to remove unexposed areas of the photoresist that is carried out by various chemical liquids. Then the chemical etching operation is carried out in spray etchant machine. The selected etchant for workpiece material is heated up to 50-55 °C depending on the spray machine allowance and etchant is sprayed from nozzles onto the workpiece surface. Removal of photoresist film from etched workpiece surface is the last stage of the PCM [1-5].

3. SELECTION OF PCM PARAMETERS FOR ENGINEERING MATERIALS

There are two vital PCM parameters for any engineering materials; those are selection of etchant and etching temperature. These two parameters have major effects on etch rate and surface roughness. Moreover, the additions of some chemicals such as hydrochloric acid, nitric acid and sodium chloride improve the etching performance of material.

Etchants are the most influential factor in the PCM of any material. The best possible etchant should have properties such as high etch rate, minimum undercut, compatibility with commonly used photoresists, high dissolved-material capacity, economic regeneration, etched material recovery, and easy control of process [7-9].

Different etchants are commercially available or the required etchant can be prepared in factory. Preparation of etchant for workpiece material should be carried out according to the corrosive resistance of the material. High corrosion resistance materials require high level of etchant concentration.

Ferric chloride ($FeCl_3$) is the most widely studied and commercially used etchant in the PCM application. It is mainly used for etching all iron-based alloys as well as nickel, Inconel, copper and its alloys, aluminium and its alloys, etc. The selected etchant concentration is around 2.1-3.4 Mol., higher concentration is used for corrosion resistance materials such as stainless steel. The etching temperature should be kept as high as possible the etchant machine allowed that would be up to 45-55°C. Some chemical additives are used to improve etching performance like hydrochloric acid, nitric acid and sodium chloride. Various regeneration processes are available for this etchant that makes the etching process more economical and environmentally accepted [10-14].

Cupric chloride ($CuCl_2$) is generally applied for copper and copper based alloys in electronics industry because various regeneration systems are available for the waste etchant. The etchant concentration is recommended around 2.1-2.4 Mol. The addition of hydrochloric acid is kept around 1-2 Mol increases etching rate. The etching temperature is 50-55°C. The importance of this etchant is regeneration of waste etchant and recovery of etched copper could be carried out simultaneously. Therefore the etchant is economical solution for copper-based alloys, particularly for copper etching [7-8,15-19].

Alkaline etchants are introduced for the PCM of copper in the fabrication of electronic components such as printed circuit board etc. They are prepared by the supplier and taken back for regeneration of used etchant. These etchant are expensive and generally selected for high volume of copper etching operations [7-8,15-16].

Corrosion resistance materials such as titanium, silicon and glass could be etched by diluted hydrofluoric acid. This etchant is very hazardous; hence major precautions must be taken for etching of these types of materials [1,7].

It should be known that the selections of PCM parameters for engineering materials are also limited by environmental restrictions. This is due to used etchant which is not fully compatible with environment. Therefore the selection of etchant, particularly, should be carried out with selection of suitable waste etchant regeneration process [7,8,20-22]. Advancements in the chemical industry are presenting achievements to adapt more environmentally acceptable chemicals for the PCM process. Moreover, advanced control and monitor systems would make the process totally controlled.

4. CONCLUSION

This study aimed to provide useful information about one of the least known nontraditional machining processes, which is PCM and its applications in shaping engineering materials. The selections of machining parameters in PCM are based on etchant and etching temperature. The selection of etchant is completed by the workpiece material. Ferric chloride etchant is widely used for iron based materials. Moreover this etchant can be used for copper and its alloys, aluminium and its alloys, nickel and its alloys etc. Cupric chloride is mainly used for copper and its alloys. Hydrofluoric acid is very dangerous and used for corrosion resistance alloys. The etching temperature is selected according to etching machine guideline. This value for ferric chloride and cupric chloride is around 45-55 °C.

Major problem in PCM application is environmental legislations. The process uses various chemical liquids for cleaning, developing, etching and rinsing operations. They are not fully environmentally friendly. The vital step is to find solutions for waste/used etchant, because high volumes of waste etchant are produced. These wastes are not allowed to dispose to sewage system due to their hazardous effects. Economical and successful regeneration processes for waste etchants such as ferric chloride, cupric chloride and alkaline etchants are available. Moreover, some regeneration processes contain recovery of etched material.

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