NEW DESIGN AND DEVELOPMENT OF TECHNOLOGY ON ELECTRO PHOTOCHEMICAL MILLING PROCESS

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Abstract

One of the un conventional milling processes is an Electro Photochemical Milling that has gained popularity owing to its efficiency to work on materials that are otherwise difficult to handle by the traditional methods. The Process of electro photochemical milling (often abbreviated as EPCM, and sometimes referred to as chemical or chemical etching) is a technique for manufacturing high-precision flat metal parts, by electrochemically etching away the unwanted materials, a photographically prepared mask is used to protect the metal that is to remain after the etching process. This method gives good surface finish in addition to the formation of the pattern on the material surface. Also it enables to work on the complex parts and thinner materials. The experiment shows that how Electro photochemical milling (EPCM), which is a hybrid of Electrochemical and Photo chemical milling, can be used to generate intricate designs on very thin metal foils with good surface finish and edge characteristics.

Key word: Electro photochemical milling, etching, lithographic, photoresist etc.

1. Introduction

The principle of ECM is often characterized as "reverse electroplating," in that it removes material instead of adding it.[2] It is similar in concept to electrical discharge machining (EDM) in that a high current is passed between an electrode and the part, through an electrolytic material removal process having a negatively charged electrode (cathode), a conductive fluid (electrolyte), and a conductive work piece (anode); however, in ECM there is no tool wear.[1] The ECM cutting tool is guided along the desired path close to the work but without touching the piece. Unlike EDM, however, no sparks are created. High metal removal rates are possible with ECM, with no thermal or mechanical stresses being transferred to the part, and mirror surface finishes can be achieved

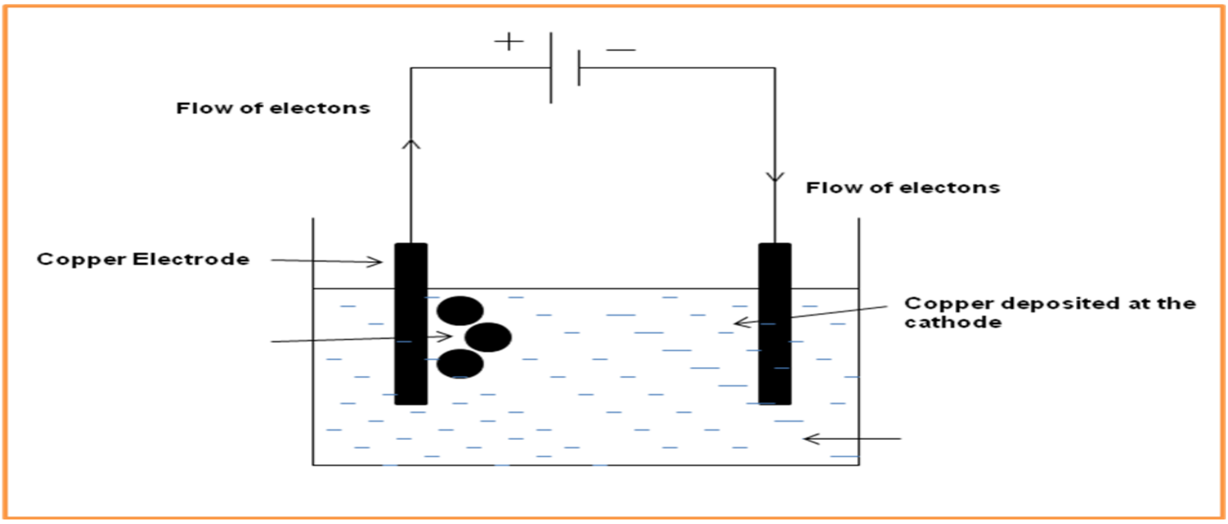

Fig 1a

Electrochemical milling turns out to be first proposed in 1929, when a Russian, W. Gussef, filed a patent for an electrochemical milling process with many features almost identical to the process as now practiced. Furthermore an American, Burgess, had demonstrated the possibility of the process in 1941. He drew attention to the striking differences between the mechanical and electrolytic methods of removing the metal, the first being the method of 'brute force violence' compared with the cool, steady non-deforming magic of the electrolytic process. However, despite the attractions of the process it was more than ten years before it was found possible to control the action to permit the process to be used in industry.

As a practical process electrophoto chemical milling, as distinct from electrochemical milling, probably had its birth in the United Stated when the Battelle Memorial Institute, sponsored by the Cleveland Twist Drill Company, developed an electrochemical method for sharpening carbide - tipped drills. This was accomplished and patent was filed (British Patent No. 854541) in 1954. The two main lines of approach have been followed in the attempt to overcome the problem out lined above-thermal methods and chemical methods, both characterized by the fact that the rate at which metal can be removed by their use is independent of the hardness of the work piece.

Electro Photochemical milling is a hybrid of Photo Chemical Milling and Electrochemical Milling. It forms a non-traditional milling in which the removal of metal is accomplished by electrochemical reactions. The desired pattern to be etched on the surface is formed by photo lithography techniques that include cleaning of the sample, the preparation of the photographic mask, application of the Photoresist on the work piece and the generation of pattern to be etched on the piece on exposure to suitable UV radiations. This method is thus used to cover the work piece with the mask in such a way that only the portions to be etched remain exposed. The etching is done by electro polishing. This is an electrolytic method in which the metal removal is achieved by electrochemical dissolution of an anodically polarized work piece. The principle is the reverse of electroplating; in addition to etching , it is possible to get good surface finish. Thus this method is popular for the production of complex configurations in thin materials and for production of delicate parts that could be easily damaged by the forces of conventional cutting tools. This method is also applied for high strength and high resistant alloys and materials that are difficult to cut by the conventional methods.

2. Electrophotochemical milling process

EPCM includes mainly two processes: photolithography and etching by Electro polishing.

2.1 Photolithography

Photolithography is the process of transferring geometric shapes on a mask to the surface of a silicon wafer. The steps involved in the photolithographic process are wafer cleaning, barrier layer formation, Photoresist application, soft baking, mask alignment, exposure and development, and hard-baking. Pattern formation by photolithography techniques is based on the application of polymer film in the desired configuration to metal or insulator films covering the entire substrate surface. The pattern of the polymer mask is repeated in the metal or insulator film by etching away the unprotected portions. The mask is generated by using a photosensitive polymer material (photo resist), whose molecular structure and solubility changes on irradiation with U.V. light.

2.2 Etching

Electro polishing is an electrochemical process based on the principles of the reverse of electroplating.

The functions of an ideal polishing process, in addition to etching, can be distinguished as

a. Smoothing by elimination of the large-scale irregularities: This is by the formation of relatively thick viscous layer of reactions products around the anode.
b. Brightening by removal of small irregularities: The formation of thin film on the surface of the anode controls the brightening action.

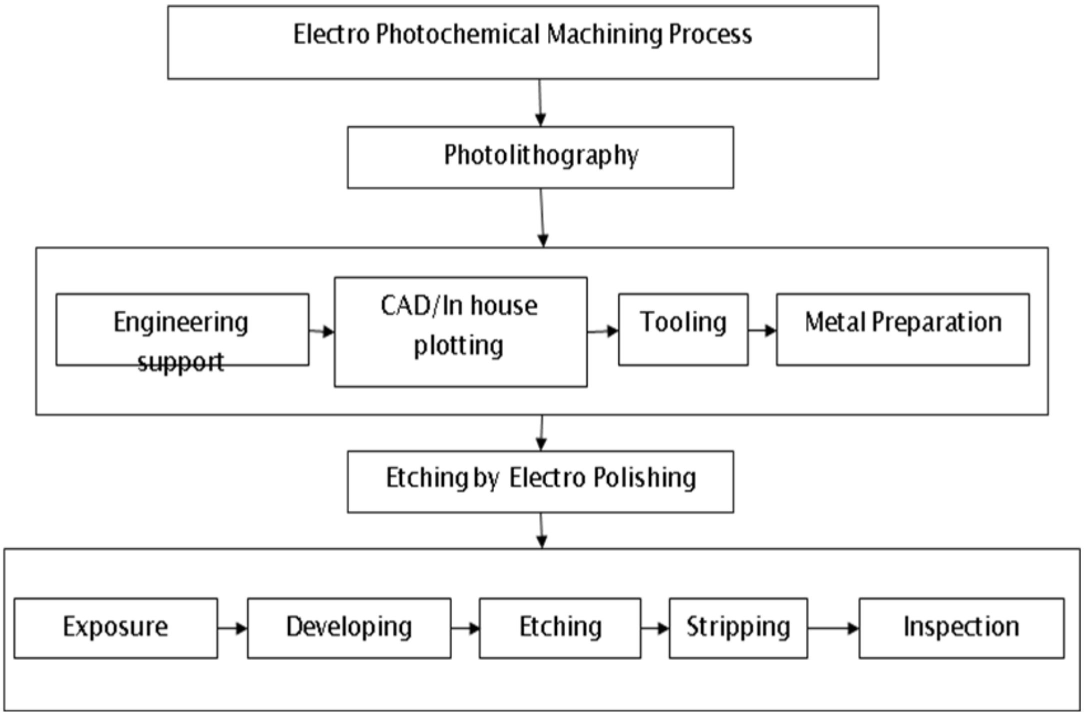

Fig 1. Electrophotochemical milling process

3.
Process requirements of electro photo chemical milling

Requirement of the cell for Electro Polishing: the principal requirements of the Electro polishing cell are following

a) The anode connections should be constructed so that the specimen may be removed from the cell easily and quickly for washing and subsequent treatment. It should be made of a corrosion resistant material, or else covered with some inert film so that only the specimen is exposed to the solution.

b) Only the portion of the specimen to be polished should be in contact with the electrolyte, this can be done by covering rest of the sample be paraffin wax or a layer of Photoresist.

c) The position of the specimen with respect to the cathode should remain fixed during electrolysis, so that no unnecessary variation of the internal resistance of the cell occurs. Whether the work piece has to be kept horizontal or in vertical position depends on the flow of the electrolyte in the system. This is explained properly in the later part of the report.

d) The cathode should be as large as possible so that the deposit is distributed sparsely over the surface and the danger of discrete particles leaving the cathode and interfering with the polishing process is reduced to a minimum.

e) The temperature of the electrolyte should be kept constant during the process.

f) Cathode material should not react with the electrolyte.

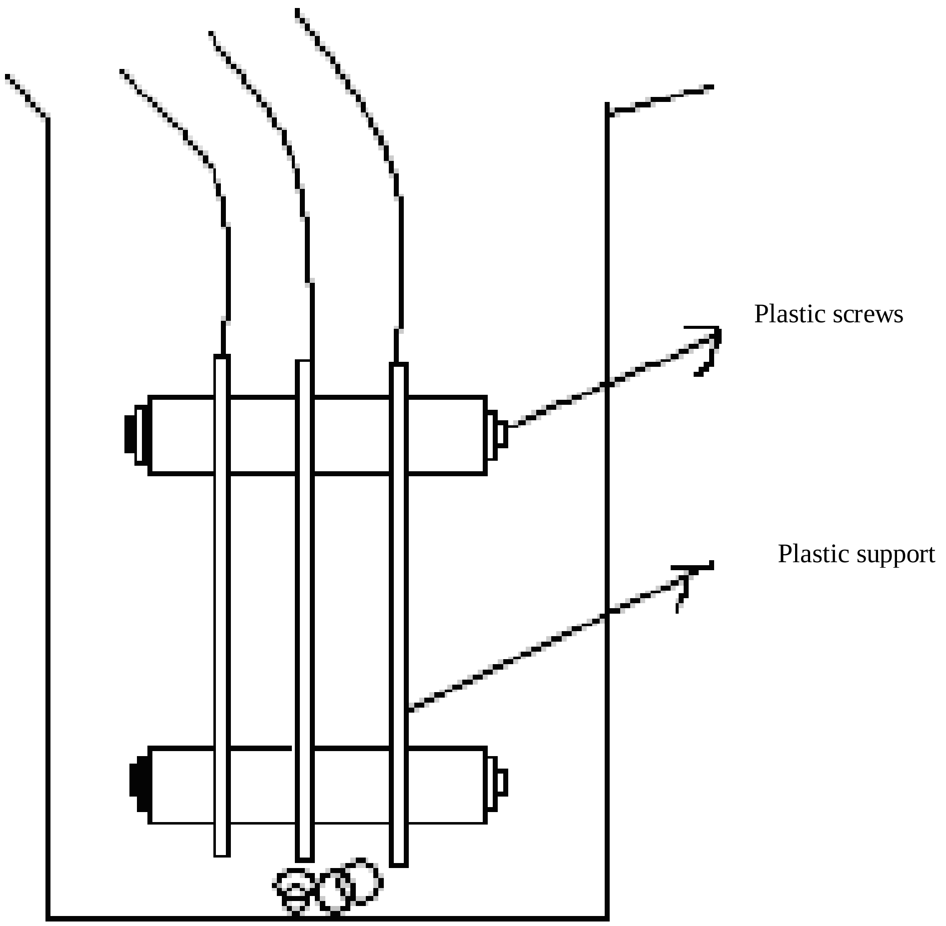

Fig 2. Vessel for electro photochemical attachment

4. Factors influencing electrophotochemical milling

The various factors that influence the electrophotochemical milling are explained below.

4.1 Tool Material

The material chosen as the tool should be able to withstand the chemical reaction during electrolysis. So the tool should be typically non-reactive, non-corrosive and should withstand the high temperature during the process.

4.2 Solution Preparation

The substance which facilitates the electrolysis is called as the solution. It depends upon the choice of the electrolyte. Each solution is effective for particular types of material.

4.3 Temperature of the electrolyte

The temperature should be controlled and maintained within the safe limit for better result and increased life of the equipments

4.4 Agitation of the electrolyte

Agitating the electrolysis with a stirrer determines the rate of the electrolytic reaction. Stirring action aids in better mixing of electrolyte and increases the reaction rate.

4.5 Initial preparation of the surface

The surface to be machined using electrophotochemical method should be prepared before use. Preparation includes polishing (removing burrs).

4.6 Time of treatment

The time of treatment has direct influence over the quality of surface finish and the quantity of the electrolyte deposited. By increasing the time of treatment the size of the metal removed can be increased.

4.7 Size of Electro polishing system

This determines the time of treatment. An increase in electro polishing system indicates that there is more quantity of electrolyte and also that bigger work pieces can also be machined. However when using smaller work pieces the time taken for treatment should also be reduced.

4.8 Ventilation

5. Pattern of the EPCM

An illustration of the electrophotochemical pattern is shown in Fig 3. The dark shaded strips are the masks which act as the coating to prevent any etching in those particular spots. However the white unshaded portion represents the areas allotted for actual matching using EPCM.

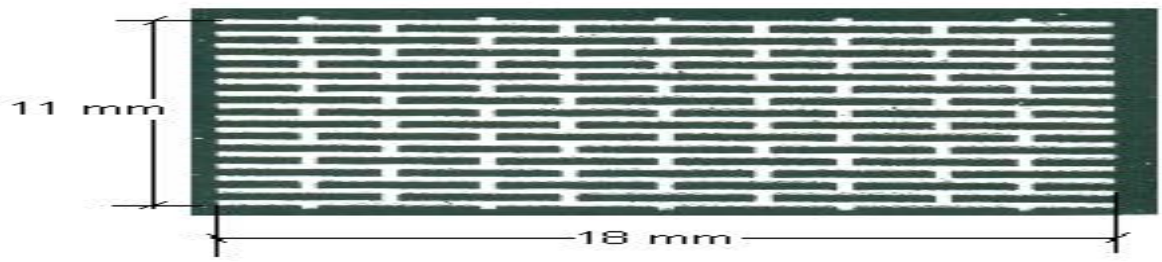

Fig 3. Mask for EPCM

6. Flow of the electrolyte

The flow of the electrolyte is very important, as it is required to take away the material, which has been cut away by the electrolysis. The direction of alignment of electrodes in electrolysis basically depends on motion of electrolyte in the beaker. The direction of motion of the electrolyte should be such that throughout the plane of the sample its speed must be very constant. In case of magnetic stirrer, etching is done in a beaker, which is kept on a plate, and a magnet below stirs electrolyte.

7. Experimental Set-Up

A schematic diagram of a laboratory setup of EPCM is shown below in Fig 4. The central bar is the workpiece which act as the anode. The anode is connected to the positive terminus of a DC supply. The negative terminus is connected to two cathodes surrounding the workpiece. Both anode and the cathodes are immersed in an electrochemical cell containing the electrolyte. A pump is used to refill fresh electrolyte into the electrochemical cell from a reservoir through the filter. During the operation any used electrolyte is removed from the electrochemical cell.

8. Conclusion

The electrophotochemical milling is a hybrid of electrolysis and photolithography milling processes, as the name indicates this process uses the milling techniques of both processes. By combining both processes we can make components and parts to fit to the tiniest space and to get accuracy with tolerances in nanometers. This process can be used to make nano-components. The process is simple yet requires careful and experienced operators to get defect free milling.

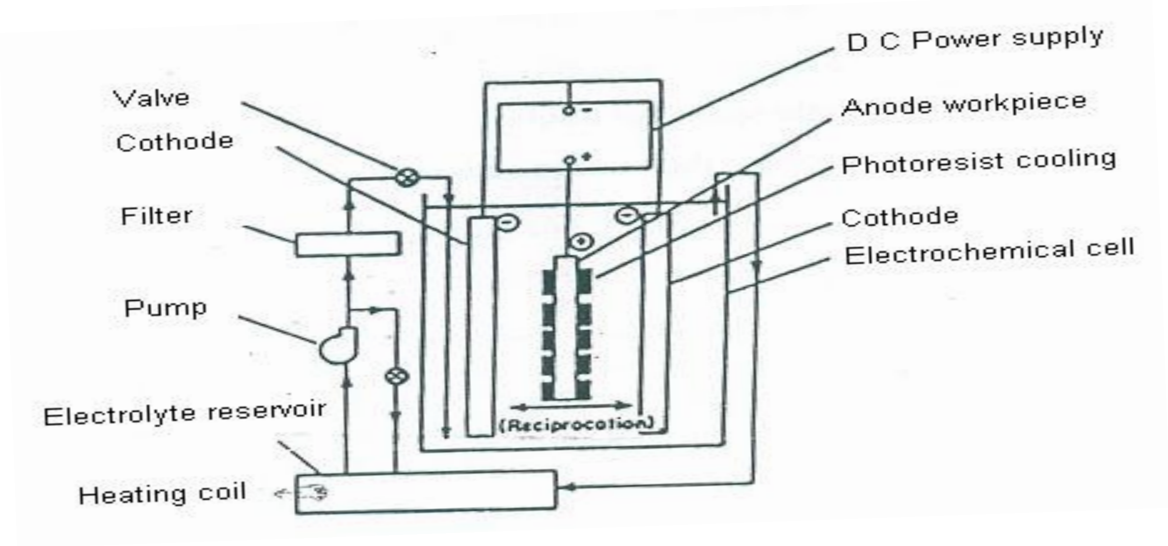

Fig 4. Schematic diagram of laboratory set-up for EPCM

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