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Fabrication of Compliant Mechanism for Micro Gripper using Photo Chemical Machining

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Abstract— Generally mechanism consists of links, joints, pairs, etc. and the force and power are transmitted by the relative motion of these parts of the mechanism. Due to the relative motion of joints, the friction occurs which leads to a deficiency in the force and power transmission. A compliant mechanism is a monolithic and joint less structure. So, it eliminates the problem of friction in the mechanism. The accurate transfer of force and power is significant while handling small size objects, sensors, assembly parts, etc. This paper is based on the development and fabrication of compliant mechanism by photo chemical machining (PCM) and their characterization. Initially, we drafted the drawing of compliant mechanism and created the photo tool of the same. Copper material was selected for the manufacturing of the mechanism. The required photo tools were generated on trace paper, and then the micro gripper was fabricated using photo chemical machining. Further, the characterization of fabricated micro grippers was performed using RAPID I Vision 5 Microscope. The error analysis of fabricated micro grippers was performed with respect to the photo tool dimensions, and the error is observed to be minimum. So, it is concluded that the micro grippers can be fabricated using PCM up to satisfactory level.

Index Terms— Compliant mechanism, Micro gripper, Photo chemical, RAPID I Vision 5 Microscope.

1 INTRODUCTION

THE mechanism is a device which is used to transfer force, motion, and power. A conventional mechanism has rigid links which are connected to joint and forms a pair. This pair allows relative motion between the links. Due to the availability of joints in this mechanism, while transferring force, motion, and power, friction occurs at the joints, which result in the inaccurate transfer of inputs given to it. Moreover, the compliant mechanism is a monolithic structure and gains motion from the deflection of flexible members instead of the use of links, joints, and pairs. So, the problem of friction is eliminated with the use of this mechanism. Due to the absence of friction the compliant mechanisms give accurate and precise motion. Also, it possesses less wear and which results in less maintenance of mechanism [1]. The compliant mechanism is essential in the development and manufacturing of micro gripper. Because the micro grippers are handling the component having sizes in millimeters or microns where the characteristics of the compliant mechanism are very useful, also, the problem of handling of micro-optical and micro-electrical elements in Nano or micrometer range can be solved by using special micro gripper. Nowadays, the micro grippers are used in the wide varieties of fields like manufacturing industry, Electronics, Medical and Biological field, Material Research and in the assembly of Micro-Electro-Mechanical Systems (MEMS) [2].

The compliant mechanism is of smaller size, so for manufacturing of such mechanism, non-conventional machining processes are essential. There are various non-conventional machining methods which can be employed for manufacturing of compliant mechanism. The Photo chemical machining (PCM) is one of the non-conventional machining processes and having characteristics which are useful to fabricate the components of smaller sizes like compliant mechanism. Also, PCM produces a burr free and stress-free flat complex metal component. The machining takes place using a controlled dissolution of work-piece material by contact with the strong chemical solution. Conventional machining tools often leave behind burrs or imperfection in the metal. These slight imperfection results in loss of uniformity that can be avoided with PCM. The heat and friction produced by conventional machining techniques can stress lighter metal alloys, resulting in deformation and affecting hardness or strength. The etchant used in PCM uniformly dissolves the metal in predefined areas. The cost of PCM is not impacted by the number of parts features or part complexity. This makes PCM most economical option for custom metal etching of thin metal parts with complex geometry. Tooling and setup cost for PCM is considerably lower than conventional methods.

Many researchers in the recent past have reported the studies related to photo chemical machining. The PCM for copper and copper alloys like brass and German silver has been performed by using ferric chloride as the etchant. The parametric optimization studies have also been reported for copper, brass and German silver. The effect of process parameters like concentration, temperature and etching time on the performances measures like material removal rate (MRR), the surface roughness (Ra), edge deviation (ED), etc. has been reported [3], [4], [5], [6]. The parametric optimization for PCM of different hard to cut materials like Inconel alloys have been

carried out by researchers [7], [8], [9]. The PCM has also been employed for fabrication of micro features, micro channels [10], [11], [12] and can be used for micro features in hydrodynamic journal bearing [13].

From the above-reported literature, it can be noted that PCM can be effectively utilized for different materials like copper, brass, German silver and Inconel alloys, etc. The PCM is effectively utilized for the fabrication of micro channels and micro features. Very fewer studies have been reported for fabrication of compliant mechanism using PCM. So, there is a scope for manufacturing of compliant mechanism using PCM.

In this paper, an attempt has been for fabrication of compliant mechanism using PCM. The mechanism has fabricated on copper material. The characterization of the fabricated mechanism is performed using RAPID I Vision 5 Microscope.

2 METHODOLOGY

2.1 Material Selection

The copper material is used for this study. Copper is more elastic after gold and aluminum and which helps in compliant mechanism operations. The size of the specimen used is 25mm × 50mm × 0.5mm.

2.2 Experimental Procedure

The specimen surface is made clean to remove the burr, oxide layer, dust, etc. So, the photoresist can easily adhere to the surface. The PCM setup is shown in Figure 1. The cleaning of the surface is carried out by polish paper and thinner (trichloroethylene or acetone) to remove traces of grease or oil. After cleaning the specimen was dipped out in the photoresist and dried it to get a layer of photoresist on the surface of the specimen. A photo tool is a negative film of the image which is needed to be produced, and it is generated by using the CAD drawing printed on the tracing paper. The photo tool drawing of selected compliant mechanism is demonstrated in Figure 2. The generated photo tool is put on the coated specimen and exposed to the ultraviolet source. The photoresist is sensitive to the ultraviolet radiation. After U.V. exposure the specimen is held in the developer. This will remove the unexposed area of the photoresist (Negative Film Method). After that, the specimen was washed with the water and dried it. The specimen is kept in the etchant with continuous heating that dissolves the metal chemically. The characterization of the process depends upon the parameters like temperature and dilution of the etchant.

- Concentration(g/L) = 400
- Temperature (° C) = 40

At the end, the specimen was washed by using water and dried. This specimen is then placed under the RAPID I Vision 5 microscope, and the various dimension of the specimen is measured. Also, in the same way, the dimensions of the photo tool were measured.

Figure 1: Photo chemical machining Setup

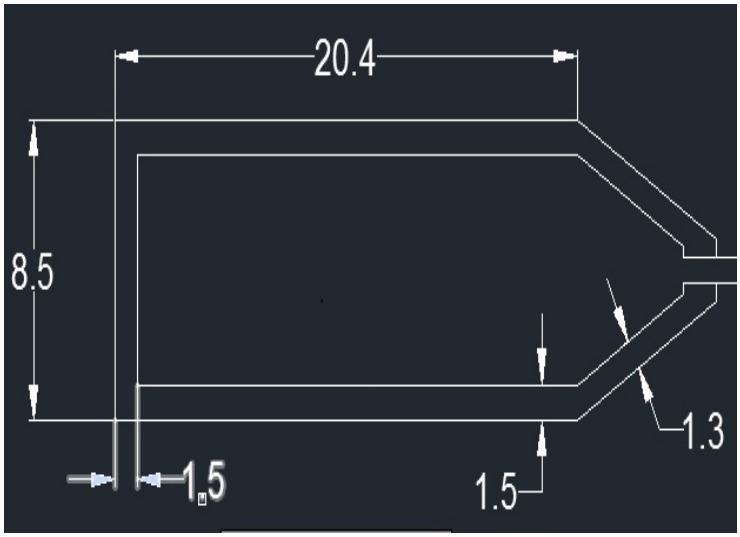

Figure 2: CAD Drawing of Photo tool

3 RESULT AND DISCUSSION

To get the exact size of the specimen by PCM process, it needs to provide some additional dimension on photo tool design of the product. So, the photo tool size is kept more than the actual size. There is some error in the desired dimension and actual dimension, and it is acceptable. So, the compliant mechanism can be manufactured by using the PCM process. The prepared photo tool is depicted in Figure 3. The characterization of photo tool is performed using RAPID I Vision 5 Microscope. The desired width of the mechanism is 1 mm. The average width for the photo tool is observed to be 1.3mm.

Using the prepared photo tool, the compliant mechanism is fabricated employing the PCM process. The fabricated compliant mechanism is shown in Figure 4. The characterization of the photo tool is performed using RAPID I Vision 5 Microscope. The average width of the fabricated compliant mechanism is 1.09 mm.

The comparative analysis for dimensions of a photo tool and fabricated compliant mechanism is carried out, and the error is calculated and presented in table 1. The average error is noted to be 0.12 mm.

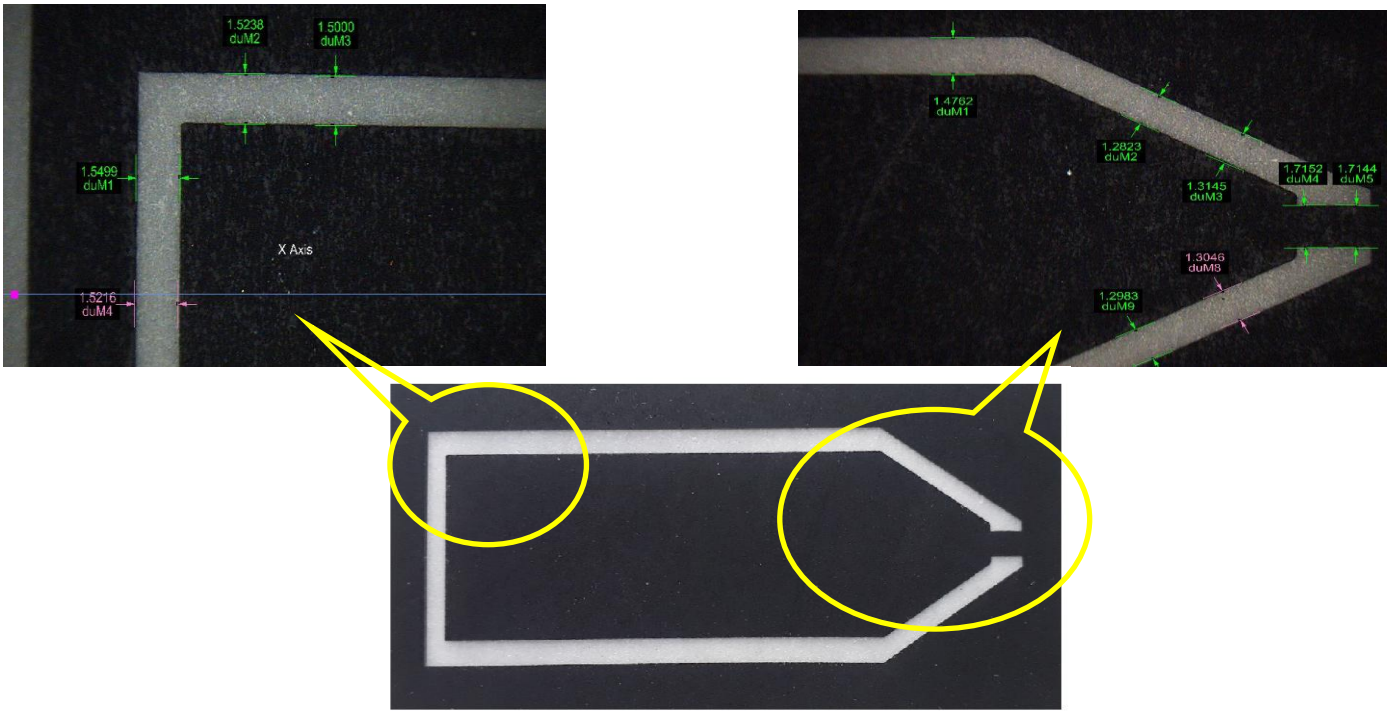

Figure 3: Characterization of the Photo tool

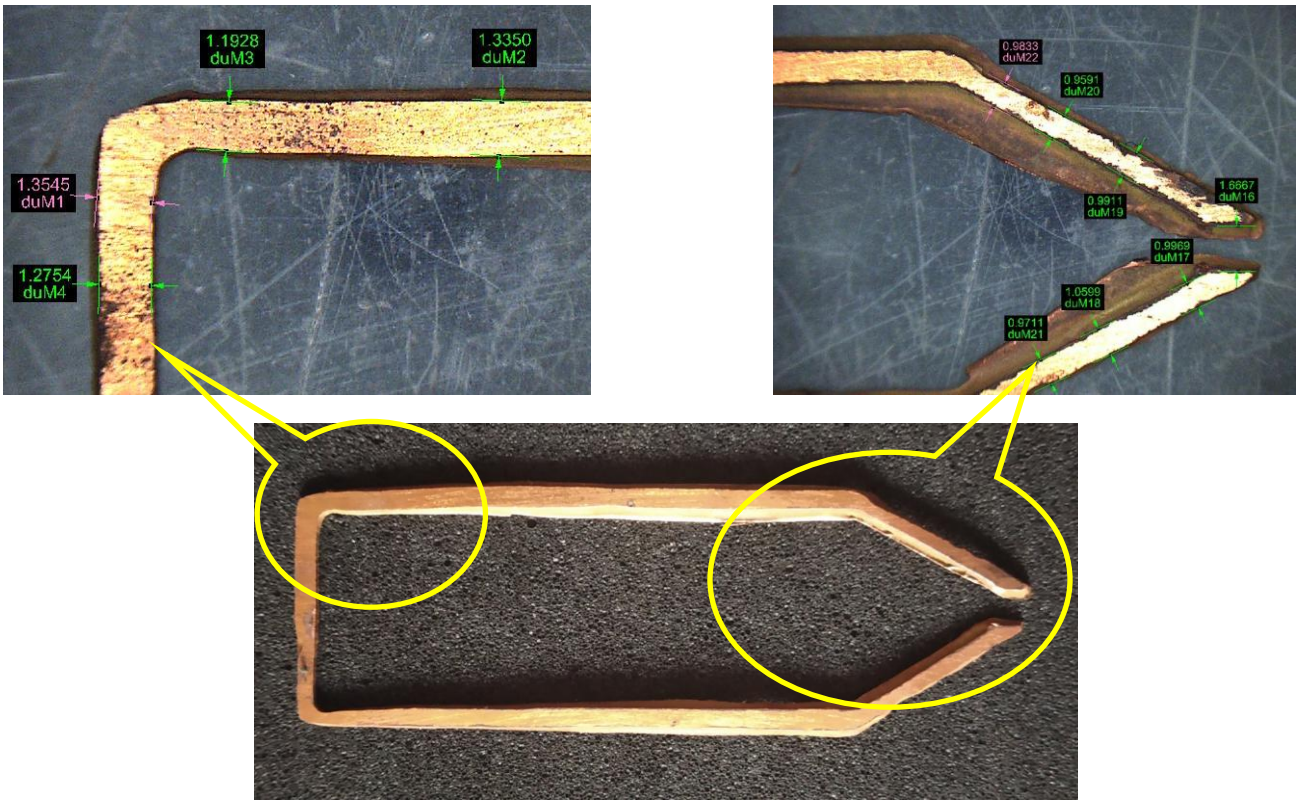

Figure 4: Characterization of fabricated Compliant Mechanism

TABLE 1 DIMENSIONAL ANALYSIS OF SPECIMEN

Sr. No.	Part Name	Desired Dimension (mm)	Photo tool Dimension (mm)	Actual Dimension (mm)	Error (mm)
1.	Gap between Jaws	1.5	1.7152	1.6667	0.1667
2.	Tapered Arm	1	1.2823	0.9833	0.0167
3.	Straight Arm	1	1.4762	1.0952	0.0952
4.	End Part	1	1.5438	1.1928	0.1928

4. CONCLUSION

Micro Electric Mechanical System or Micro systems is an emerging technology, and it has a significant potential to reshape human life patterns in the future. The micro gripper is playing an important role in handling of these micron sizes objects and to manufacture the micro gripper compliant mechanism is needed. The fabrication of compliant mechanism using PCM is carried out on copper material using ferric chloride as the etchant. The photo tool having an average width of 1.3 mm is prepared, and the compliant mechanism with an average width of 1.09 mm is fabricated using PCM. The error analysis for photo tool and the fabricated compliant mechanism is performed, and the average error is observed to be 0.12 mm.

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