# Fabrication of Electroplated Cu Tool Electrodes for Micro-EDM using a Si Micromold

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**Abstract**
Micro Electro Discharge Machining (Micro-EDM) provides a potential for the fabrication of micro cavities in materials independently of their respective hardness. Such cavities may serve many purposes, like lubrication grooves in the tool industry to name just one example. To match the desired application, specific types and shapes of tool electrodes are required. Using Si structures as patterns for a micro electroplating process, truncated and non-truncated pyramid shaped microelectrodes may be fabricated with high precision. Si is a well-understood wafer material for the fabrication of Micro Electro-mechanical Systems (MEMS). Pyramid shaped grooves can be created in the surface of single crystalline Si due to the material's anisotropic etching properties. Using KOH as a wet chemical etching agent, Si will form wall shapes and angles, which are dependent on the crystallographic orientation of the Si. For the fabrication of pyramid electrodes, Si (100) was used providing a wall angle of 54.7° after wet chemical etching. For these experiments, Cu was used as tool electrode material for EDM. Cu electrodes fabricated for Micro-EDM featured a tool wear comparable to the one of a conventional Cu wire electrode.

## 1 Introduction

Micro Electro Discharge Machining (Micro-EDM) is a fabrication process for micro parts based on the thermal material removal principle without a mechanical contact between the tool electrode and the workpiece. Mikro-EDM provides for creating features like holes and slots as well as freeform surfaces. Both the electrode and the workpiece materials must be electrically conductive [1]. Previous work centered on fabricating round holes by applying electroplated cylindrical micro electrodes. Among other, Cu was found to be an appropriate electrode material. Tests revealed, that the geometry of the resulting micro holes depended on the electrode surface roughness and geometries [2, 3]. A key for achieving a good micro electrode geometry was to use a photosensitive epoxy as a mold and removing it by a plasma etching process [4]. This paper describes extending the Micro-EDM process from round holes to a pyramid pattern.

## 2 Micro-EDM Concept and Electrode Fabrication

Figure 1 demonstrates, how the Micro-EDM concept may be extended to create simple three-dimensional recessions: the electrode is pyramid (or truncated pyramid) shaped and creates its negative in the workpiece.

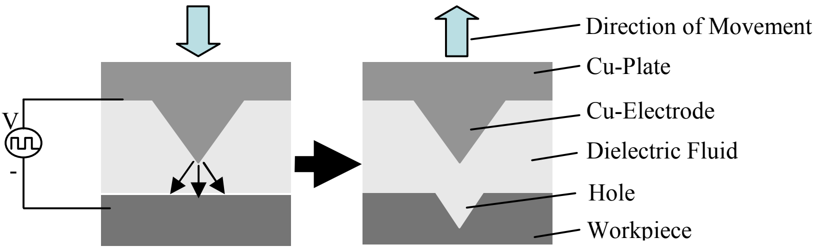


Figure 1: Concept of Micro-EDM machining of a pyramid-shaped recession

Using a negative is also applied to creating the micro mold: by taking advantage of the anisotropic etching capabilities of single crystalline Si, the negative pyramid-shaped structure ultimately desired in the workpiece is created in a Si wafer. Next, a Cu layer is deposited on top of the Si wafer surface. The material ending up in the cavities later represents the Micro-EDM electrode. By removing the Si wafer material in a KOH etching process, the tool and its base is released. This process was applied to creating both truncated and non-truncated pyramids as Micro-EDM electrodes.

### 2.1 Si Micromold Fabrication

For the fabrication of the electrodes, Si (100) was used providing a wall angle of 54.7° after etching. First, a Cr/Au layer was deposited on the topside of the Si wafer using Physical Vapor Deposition (PVD). Then, a 500 nm $Si_3N_4$ thin-film used as a mask for KOH etching was deposited using Plasma Enhanced Chemical Vapor Deposition (PECVD) on both sides of the wafer. The $Si_3N_4$ layer was patterned using

Ion Beam Etching (IBE) using an etching mask made of photoresist (Fig 2). After the selective removal of $Si_3N_4$ and Cr/Au, the AZ photomask was stripped. Then, the Si was etched using the patterned $Si_3N_4$ layer (on top of the Cr/Au film) as an etching mask in a KOH bath to form the truncated or non-truncated pyramid shaped cavities. After etching, the depth was 250 µm for the truncated pyramids and 175 µm for the regular ones.

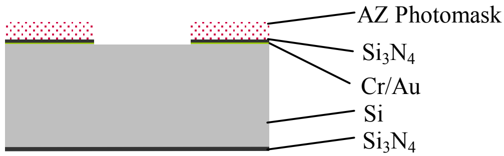


Figure 2: $Si_3N_4$ mask Fabrication using IBE

After etching, a thin layer of $Si_3N_4$ was deposited onto the wafer. Then, a Cr/Au seed layer required for the electrical contact during electroplating was deposited using PVD.

### 2.2 Cu Tool Electrode Fabrication

Cu was deposited by electroplating on the whole wafer surface (Figure 3). Then, the Si wafer material was removed in a KOH bath and the $Si_3N_4$ layers were removed applying microwave plasma etching using $O_2$ and $CF_4$ as process gases. Figure 4 depicts a top view of the Cu test structures.

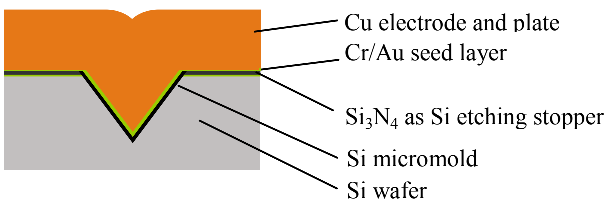


Figure 3: Schematic representation of the Micro-EDM electrode material deposition

## 3 Conclusion

By taking advantage of the anisotropic etching capabilities of single crystalline Si, a process for fabricating simple three-dimensional tool electrodes for Micro-EDM could be developed. It could be demonstrated, that electrodes with both truncated pyramid as well as regular pyramid shapes could be created.

a) b)

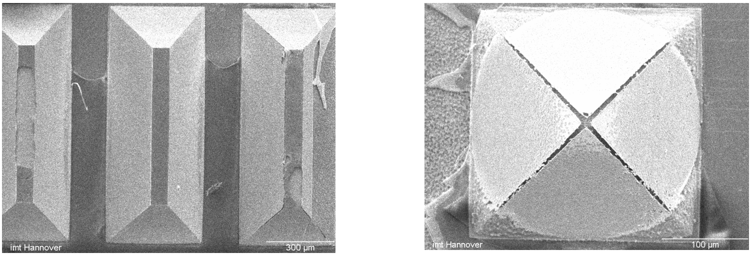


Figure 4: SEM images of 3D electroplated Cu electrodes: a) truncated pyramid tool electrodes, 250 µm high; b) pyramid electrode with a height of 170 µm

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**References:**

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