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A HIGHLY FLEXIBLE MANUFACTURING TECHNIQUE FOR MICROELECTRODE ARRAY FABRICATION

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Abstract – **A new technique for manufacturing microelectrode arrays is described and assessed. This technique uses wire Electrical Discharge Machining (wire EDM) to form detailed array structures from a single sample of solid metal. Chemical etching can then be used to increase the electrode aspect ratios. Electrode lengths of 5 mm, widths of 40 μm, and spacings of 250 μm have been fabricated using this technique. Arrays of electrodes of varying lengths can also be fabricated. For intracortical recording applications, the signal paths are isolated from one another by securing an insulating substrate.**

Keywords - **Microelectrode array, electrical discharge machining (EDM), neural implant**

I. Introduction

Advancements in medical and biological research, medical devices, and medical implants have created a need for the construction of structures of increasingly smaller dimensions. These structures often require large aspect ratios and high spatial resolutions.

Neuroscience has quickly become an area where such structures are common. Implants in mammals serve as scientific tools and may soon develop into medical devices [1]. A key component of these recording systems is the mechanical front-end, commonly referred to as a microelectrode array. Currently, microelectrode arrays consist of a flat substrate out of which extend 25 to 100 parallel 1-mm-long probes, which are generally evenly spaced at about 500 μm. Some exposed, conductive part of these probes is normally used for neural signal recording at a depth of about 1 mm from the surface of the brain.

These microstructures are commonly fabricated using silicon-wafer-based processes. Two successful approaches are a single-component, silicon-based design developed at the University of Utah [2, 3], and a contrasting assembly technique, also silicon-based, undertaken at the University of Michigan [4, 5].

In this paper, a metal-based design approach is described. This microelectrode assembly was developed for the Telemetric Electrode Array System (TEAS) project, a project which aims to develop a wireless intracortical recording device designed for motor cortex studies in nonhuman primates [6]. The TEAS microelectrode array is machined from solid metal using a wire Electrical Discharge Machining (wire EDM) based technique. It is then mounted in a polyimide substrate and removed from its metal base [7]. Following this step, the array is connected to a flexible printed circuit board connector cable, which joins the microelectrode array to the electronics module [8].

II. Methodology

A. Wire Electrical Discharge Machining Process

Electrical Discharge Machining (EDM) uses the erosive effects of electrical discharge between two electrodes, separated by a dielectric fluid, to machine metal. It is a forceless process that is performed in a highly parameterized, complex, and controlled environment. It is a Computer Numerically Controlled (CNC) process, which gives highly repeatable results. Because it is Computer Aided Design (CAD) based, structure modifications are straightforward to implement and predict.

Wire EDM uses a continuously fed wire as the machining electrode and is capable of producing a submicron surface finish by performing several passes. The microelectrode arrays are fabricated by first performing an intricate cut through one plane, rotating the array ninety degrees with respect to the wire, and then repeating the cut. Fig. 1 shows a machined array. The ridges on the electrodes are used for placement of the substrate during assembly.

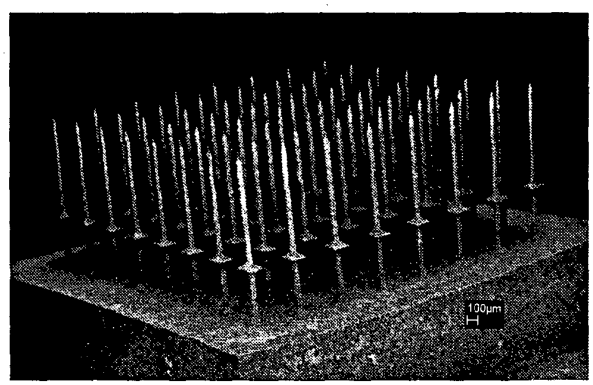

Fig. 1. SEM image of a microelectrode array that was electrical discharge machined from a single piece of solid titanium. This array has since undergone a chemical etching process. Note that the electrode widths have decreased from 80 μm to 40 μm and that the finer features remain.

Honeycomb-shaped arrays of hexagonal microelectrodes have also been machined by performing three cuts and by rotating the piece by sixty degrees after performing each cut.

B. Microelectrode Materials

Stainless steel, titanium (99.6+%), and titanium-aluminum-vanadium alloy (Ti90-Al6-V4) are the metals that have been primarily used in the microelectrode fabrication process. They were chosen due to their strengths, their resistances to corrosion, and their biocompatibilities. It should be noted, however, that these structures are normally electroplated and coated with parylene [7], so the machined metal is not normally in direct contact with the brain. Similar structures could be fabricated using other metals, for example copper, aluminum, or platinum.

C. Chemical Etching Process

The aspect ratio of a given microelectrode array structure can be increased by using an acid etching process. This is demonstrated in Fig. 1, where titanium microelectrodes, originally machined to widths of 80 μm, were chemically etched using a heated hydrochloric acid (HCl, 37% approx.) bath. Electrode widths of about 40 μm were obtained in this case, but this process can yield even finer microelectrodes. As can be seen in the figure, the electrode detail was well maintained during this process.

This etching process also serves to remove oxide from the electrode surfaces, a desirable step before an electroplating or coating process is performed [7].

III. Results

Structures with microelectrode lengths exceeding 5 mm have been machined successfully using this technique. Though electrodes of final lengths of about 1 mm are normally constructed, the structure shown in Fig. 2 demonstrates that this technique can be used to produce arrays of electrodes consisting of a range of lengths.

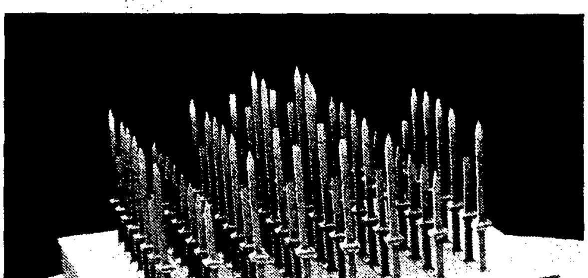

Fig. 2. SEM image of a titanium-aluminum-vanadium alloy microelectrode array that was electrical discharge machined to have electrodes of varying lengths. There are three electrode lengths present in this example: roughly 0.5mm, 1mm, and 1.5 mm from the ledge features to the electrode tips.

Microelectrode arrays with intra-electrode-spacings of 250 μm have been machined using this technique. The spacing is limited only by the size of the wire used in the EDM process. The width of a cut into bulk metal is typically the diameter of the wire plus some additional offset, normally a fraction of the wire diameter. As can be seen in Fig. 2, intricate surface features can be designed and manufactured into the electrodes themselves. In this case, ridges are designed as part of the electrodes in order to aid in assembly. A substrate can then be accurately and reliably secured to the electrodes. EDM is later used to remove the needles from the metal base [7].

IV. Conclusion

A brief overview of the capabilities of a new technique for manufacturing microelectrode arrays has been presented. Once the parameters and details have been determined, this CNC EDM-based technique is capable of predictably creating array structures with a high degree of repeatability. It is capable of creating a variety of shapes, intricate surface features, and a submicron surface finish. CAD is also inherent in the design and manufacturing process, so any modifications can be made efficiently and predictably. As the density and resolution required for microelectrode applications increases in the future, these capabilities will likely prove to be valuable.

Acknowledgment

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