Spike Neuro's Ultraflexible Surface Electrocorticography Microelectrodes

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ABSTRACT

This white paper presents the development and characterization of an innovative ultraflexible 16-channel Electrocorticography (ECoG) microelectrode array for recording brain signals. Leveraging novel fabrication techniques, we constructed thin (<3um) microelectrode patterns on a sub 8um Polyimide film, enhancing adhesion properties crucial for chronic interfaces. Our packaging, utilizing 76um PCB technology, ensures lightweight construction, complemented by Omnetics connector compatibility. In vivo studies involving mouse implantation demonstrated the efficacy of our flexible ECoG microelectrodes in recording brain signals, indicating promising potential for neuroscientific research and clinical applications.

1 INTRODUCTION

Within the domain of neuroscience, the pursuit of understanding brain function at a finer resolution has spurred the evolution of recording technologies. Among these, Electrocorticography (ECoG) has emerged as a powerful tool, enabling direct cortical surface measurements with remarkable spatial and temporal resolution[2]. However, traditional ECoG electrode arrays often posed limitations in terms of flexibility, durability, and invasiveness. Addressing these challenges head-on, Spike Neuro has developed a groundbreaking solution: thin film polyimide microelectrodes. These microelectrodes represent a significant departure from conventional approaches, boasting ultraflexible 16-channel arrays meticulously etched onto a thin Polyimide film. Leveraging proprietary fabrication techniques, Spike Neuro has achieved a delicate balance, ensuring electrode robustness while minimizing tissue trauma during implantation. This technology not only promises enhanced signal fidelity but also opens avenues for chronic neural recordings in diverse experimental settings. In this white paper, we delve deeply into our designs, fabrication methodologies, and experimental validations that underpin Spike Neuro's groundbreaking ECoG technology.

2 MATERIALS AND METHODS

2.1 Designs

Spike Neuro offers a versatile range of ECoG designs tailored to accommodate diverse research needs. Our research has led to the identification of two highly effective designs: a 16-channel configuration and a 32-channel counterpart. The 16-channel ECoG features larger electrodes with diameters of 200um and an interelectrode spacing of 500um, providing robust signal capture capabilities. In contrast, the 32-channel design utilizes 50um electrodes with a 300um interelectrode spacing, enabling finer spatial resolution and increased channel density. Both configurations incorporate strategically placed openings to facilitate cerebral-spinal-fluid leakage, ensuring optimal conformity to the intricate contours of the brain. With electrode dimensions spanning 2500um x 2100um and 2500um x 1500um respectively, these ECoG arrays represent a harmonious blend of precision engineering and adaptability, empowering researchers to record and decipher multi-unit brain dynamics with clarity and fidelity. Fig. 1 shows the designs and connector options available, and the dimensions are offered in Table 1.

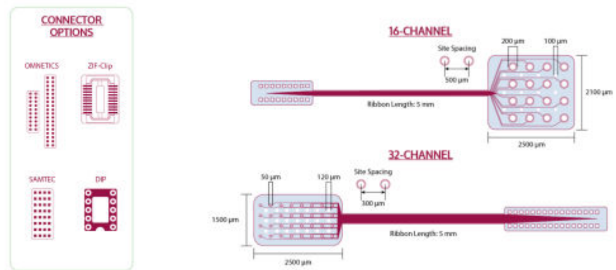

Figure 1: Spike Neuro's ECoG Designs

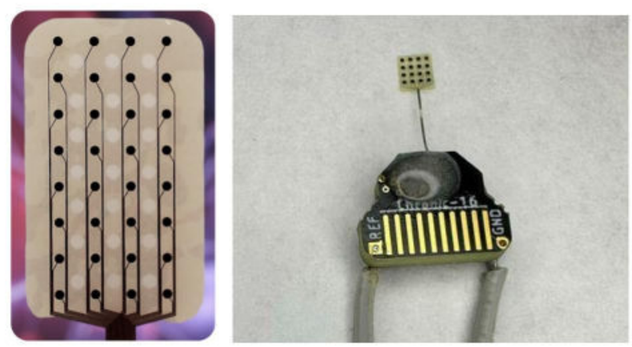

Figure 2: 32-ch ECoG and assembled 16-ch ECoG array

2.2 Fabrication of the ECoG Arrays

Spike Neuro's ECoGs are manufactured with precise microfabrication process within a class 10 cleanroom environment. The first layer put down is a 4um-thick layer of Pyralin-2610, onto which a proprietary adhesion treatment is applied, vastly enhancing the polyimide's adherence to metals and itself, a critical aspect for long-term reliability. A stack of Ti-Pt-Au-Pt-Ti is then patterned using the liftoff technique, facilitating the creation of low-conductivity

Table 1: ECoG Designs and Specifications

Channel Count	Dimensions	Electrode Diameter
16-channel	2500um x 2100um	200um
32-channel	2500um x 1500um	50um

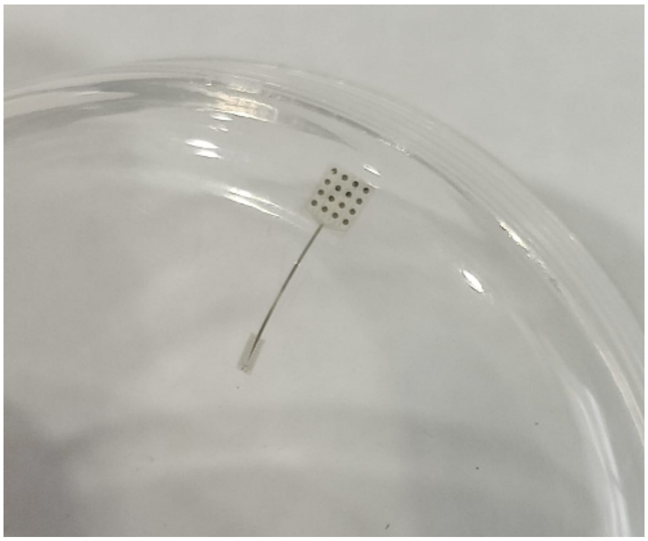

Figure 3: ECoG conforming to the shape of a glass dome

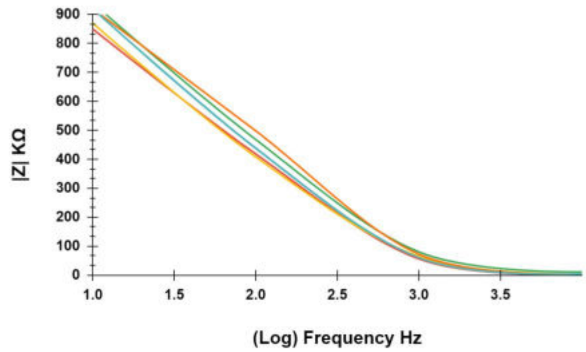

Figure 4: 16ch ECoG with an Omnetics package

channels while enabling the utilization of pseudocapacitive materials like Platinum for electrode functionality[1]. Following this, a second layer of Pyralin-2610 is spin-coated and cured to encapsulate the electrode stack. Subsequently, precise outline patterns are etched into the polyimide using SF6 and O2 plasma, defining the device's shape. Finally, the completed devices undergo a meticulous release process, soaking overnight in water before delicately peeling them using lab tweezers. The devices are then baked to relieve any inherent stress and allow them to be flat and ready for packaging.

Fig 2.and Fig 3. show the microfabricated ECoG arrays.

Table 2: Microfabrication Dimensions

Layer	Thickness	Layer Significance
Polyimide (Base)	4um	Substrate and bottom insulator
Metal Channels	500nm	Conductive channels and electrode
Polyimide(Top)	4um	Insulator

2.3 Connector Assembly and Impedance Testing

Following the fabrication process, the ECoGs undergo connector assembly and impedance testing to ensure optimal performance. The microelectrodes are meticulously bonded to a compact package utilizing ultrasonic bonding techniques and subsequently encapsulated with epoxy for added durability. To complete the assembly, an Omnetics A79014 connector is soldered onto the package, providing a reliable interface. Impedance testing is conducted using electrochemical impedance spectroscopy, with measurements performed on the assembled ECoG electrode array. Figure 4 illustrates the impedance spectral bands of the six microelectrodes measured in PBS 1X solution. The average impedance recorded at 1 kHz stands at 48.6 kΩ, indicative of the array's satisfactory electrical characteristics and suitability for neural recording applications.

2.4 In-Vivo Testing

For the in-vivo evaluation of Spike Neuro's ECoG electrode array, surgical implantation procedures were meticulously executed using a wild-type mouse at an accredited animal facility. Prior to implantation, the mouse underwent anesthesia in an induction chamber with 5.0 percent isoflurane, followed by maintenance anesthesia (1.0–2.0 percent) in oxygen until unconsciousness was achieved. Aseptic preparation involved shaving and cleaning the surgical site on the mouse's head with betadine scrub and isopropyl alcohol. The mouse was securely positioned on the robotic stereotax. The body temperature levels were monitored and controlled using a heat pad. A craniotomy was done to expose the brain surface and the rest of the scalp was cleaned with hydrogen peroxide. The ECoG electrode array, attached to a stereotaxic arm, was carefully positioned over the exposed surface. The surface was regularly irrigated with saline.

The ECoG was held in place for 4 hours and 6 sessions of 30 minutes each were recorded. All recordings were done inside a Faraday cage to minimize disruptions due to electromagnetic noise.

An Intan acquisition system along with an RHD2000 amplifier chip was used to record the data. The data was pre-processed for the line noise and other artifacts. Membrane potentials of the nearby neurons often called Local Field Potential (LFP) were observed as shown in Fig 5. by applying a band pass filter (1-70Hz)[2]. Further, Power spectral density (PSD) plots, as displayed in Fig 6. show the

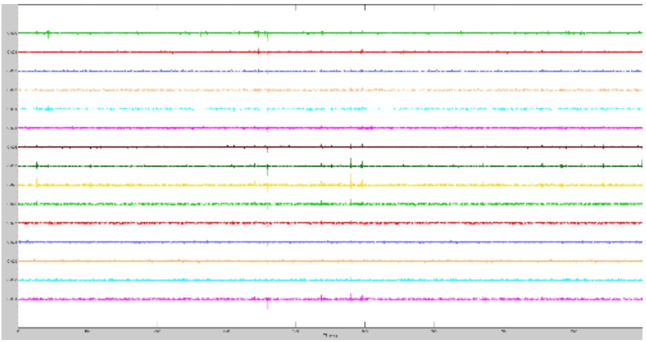

Figure 5: 16ch Local field potential (LFP) recordings from the ECoG array

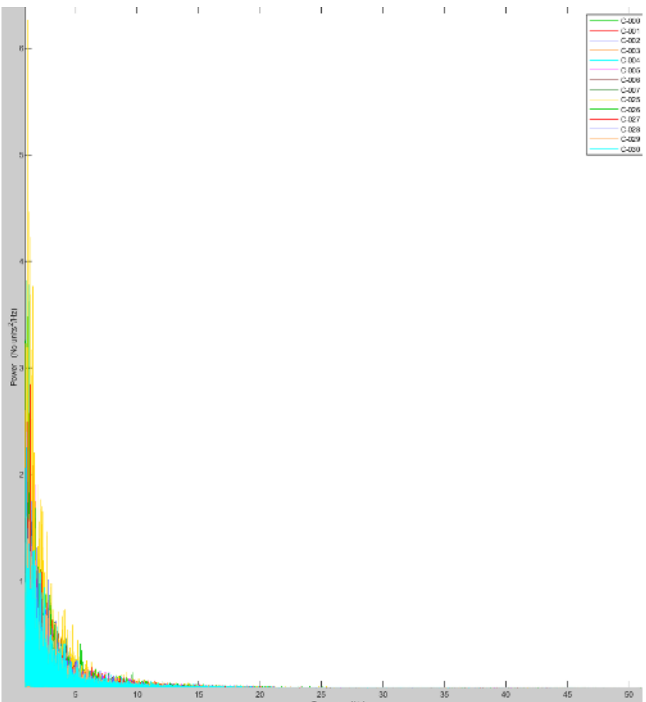

Figure 6: 16ch Power Spectral Density (PSD) plots using Fast Fourier Transform (fft)

distribution of power in the signal across different frequencies. This provided insights into the dominant frequency components present in the signal.

3 CONCLUSION

In summary, the outcomes presented in this white paper highlight the progress made by Spike Neuro in the development of its flexible ECoGs technology. Our thin polyimide-based ECoG microelectrodes represent a notable advancement, offering both thinness and high yield, alongside commendable signal-to-noise ratios. Additionally, the inclusion of drainage holes in our arrays facilitates better conformity to the brain's surface, enhancing overall reliability. We are pleased to announce that Spike Neuro's ECoGs are now commercially available, providing researchers with a valuable tool for investigating brain dynamics with enhanced precision and reliability.

REFERENCES

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[2] John P Seymour, Fan Wu, Kensall D Wise, and Euisik Yoon. 2017. State-of-the-art MEMS and microsystem tools for brain research. *Microsystems & Nanoengineering* 3, 1 (2017), 1–16.