Flexible Ear-EEG for Improved Medical Assessment

Jordan Luk, Henson Le, Moran Amit Ph.D, Tse Nga (Tina) Ng Ph.D
Department of Electrical and Computer Engineering
University of California – San Diego

Introduction

- Electroencephalograms (EEGs), are used to assess brain electrical activity. Some utilizations include epilepsy diagnosis, sleep staging, and brain-computer interfaces
- Current cap-EEG setups are highly power inefficient and do not realistically reflect everyday neural brain activity because the user is unable to move while wearing it
- The overall approach to this is an EEG design that will wrap around the ear and connect to OpenBCI for testing
- We will base our design on a previous ear EEG design[1], using a more flexible substrate for better comfortability

Objective: To create a mobile, unobtrusive, energy efficient, and cost-efficient ear-centered EEG design that will allow acquisition of brain activity in a comfortable manner.

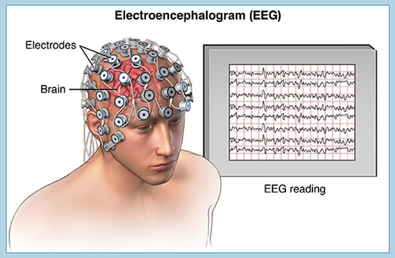

Figure 1. A representation of how an EEG works. [2]

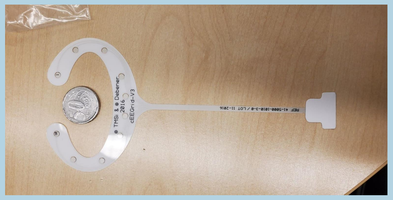

Figure 2. A plastic, non-functional prototype of the original ear-centered EEG (Bleichner and Denebar) in comparison to a nickel.

Figure 3. The application process for an ear-centered EEG compared to the traditional cap-EEG. [1]

Methodology

Substrate

- A sticky substrate was created so that the device could stick around an individual's ear
- 18 grams of polydimethylsiloxane (PDMS) was mixed with 2 grams of a crosslinking agent and modified with 70 µL of 80% ethoxylated polyethylenimine solution (PEIE) to make the substrate stick to skin
- The mixture was poured into a plexiglass mold and degassed
- The substrate was cured over a hot plate for 5 hours at 110° C; however, we had a faulty hot plate, leaving some areas of it hotter than the others
- Our substrate needed to be sticky enough to stick to skin, but not to the point where it is uncomfortable when attached or difficult to peel off
- Then the substrate was tested with a latex glove and the substrate stuck to the glove and did not leave residue

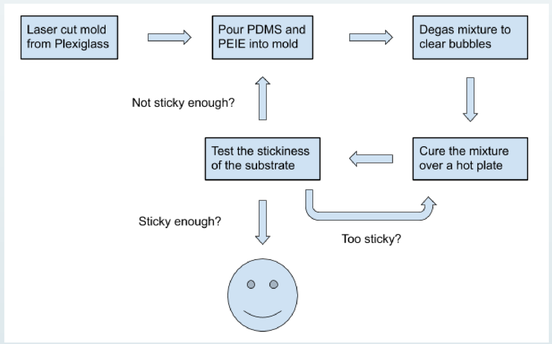

Figure 4. Process of creating a sticky substrate.

Electrodes

- Silhouette Cameo 3 cutter and Silhouette Studio software were utilized to design our template for mask
- The design was based on the shape of the original ear-centered EEG. [1] This includes:
  - 10 circular electrodes that will contact the skin
  - A wire coming out of each electrode that will be used to conduct signals

Figure 5. The Silhouette Cameo 3 cutter and a view of the Silhouette Studio software. [3]

Results

Substrate

- After a few tries, we were able to create a substrate that stuck to our glove but did not leave any residue

Electrodes

- Using the Silhouette Studio software, we were able to design a template that we will use to print out electrodes in the future

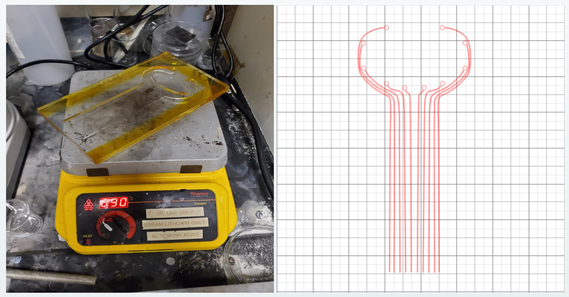

Figure 6. Transparent substrate curing on a hotplate (left), as well as the electrode and wire design (right).

Future Work

Electrodes

- This mask will be used to create the electrodes which will be fabricated from silver/silver chloride ink and mixed with Exoflex-50 to give the electrodes the crucial quality of being flexible and stretchable
- The wires of the design will be covered by a conducting polymer: poly (3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) so that only the circular electrodes will be in contact with skin [4]

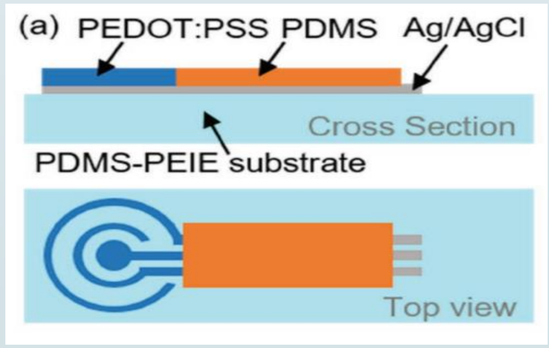

Figure 7. An image of the electrodes Kaiping Wang previously created. [4]

OpenBCI

- We will utilize open-source brain-computer interface (OpenBCI) and commercial electrodes to obtain EEG data that will be used as a control
- Then we will record data and if the data from our ear-EEG is similar to the data from the commercial electrodes then our ear-EEG works and improves upon the comfortability and obtrusiveness of the previous ear-EEG design

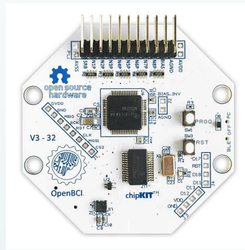

Figure 8. Image of the OpenBCI. [5]

Conclusion

EEGs can be utilized for epilepsy diagnosis, sleep staging, and brain-computer interfaces. To further improve on current EEGs, we aimed to make the substrate stick to skin without needing to apply any gel or sticky substance. We did this by mixing 18 grams of PDMS with 2 grams of crosslinking agent and modified it with 70 µL of 80% ethoxylated polyethylenimine solution (PEIE) to make the substrate stick to skin without needing to apply any gel or sticky substance. We were also able to complete a design for the electrodes to be placed onto the substrate.

Acknowledgements & References

- Guided Engineering Apprenticeship in Research (GEAR) Program
- IDEA Engineering Student Center
- Electrical and Computer Engineering faculty member Tina Ng
- P.I. Moran Amit
- Graduate Student Kaiping Wang

[1] Bleichner, Martin G., and Stefan Debener. "Concealed, Unobtrusive Ear-Centered EEG Acquisition: CEEGrids for Transparent EEG." *Frontiers*, Frontiers, 17 Mar. 2017, www.frontiersin.org/articles/10.3389/fnhum.2017.00163/full.
[2]Gold, Sam. "What a BCI Is and Why You NEED to Care." Medium, Medium, 20 Nov. 2019, medium.com/@samuelstgold/what-a-bci-is-and-why-you-need-to-care-5000aeab100.
[3]"Silhouette Cameo 3 Electronic Cutting Tool." USCutter.com, www.uscutter.com/Silhouette-Cameo-3-Cutting-Tool.
[4] Wang, K., Parekh, U., Pailla, T., Garudadri, H., Gilja, V., and Ng, T. (2017). Stretchable Dry Electrodes with Concentric Ring Geometry for Enhancing Spatial Resolution in Electrophysiology. *Advanced Healthcare Materials.*
[5]"Cyton Biosensing Board (8-Channels)." OpenBCI Online Store, shop.openbci.com/products/cyton-biosensing-board-8-channel?variant=38958638542.